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THE HISTORY OF

# A LUMP OF IRON,

## From the Mine to the Magnet.

BY

ALEXANDER WATT,

*Author of "A Lump of Coal," "A Lump of Chalk," etc.*

*WITH ILLUSTRATIONS.*

"Out of a great deal of old Iron."—SHAKESPEARE.

A. JOHNSTON,

6, PATERNOSTER BUILDINGS, LONDON, E.C.

1884.

# PREFACE.

In selecting Iron as a subject for a brief History, the Author was aware that in treating upon so great a theme he would necessarily have to leave much unsaid. He has endeavoured, however, to select from the vast accumulation of published processes and facts such varied material as would be most likely to interest the General Reader, and at the same time afford instruction to the more youthful members of the community.

In associating Magnetism with the History of Iron, the Author has, he trusts, justified himself in the Chapter referring to the Native Magnet, or Loadstone, in which many facts are brought to notice which cannot fail to prove interesting to all readers.

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# THE HISTORY

OF

# A LUMP OF IRON.

## CHAPTER I.

### Early History of the Uses of Iron.

When we reflect that the wealth and prosperity of Great Britain are chiefly due to the vast store of Coal and Iron which bounteous Nature has so lavishly bestowed upon her, much interest must necessarily attach to substances which have done, and are still doing, so much for our well-being as a nation.

Taken by itself, there is nothing very remarkable in a Lump of Iron, but we will endeavour to show, however, that few substances in nature yield a more interesting subject for reflection, while assuredly none other—excepting Coal—has proved so immensely serviceable to man. Whether we handle the delicate and exquisitely-formed needle—which passes through some hundred and twenty operations for its completion—or behold the mighty Nasmyth hammer, or the ponderous and complicated steam-engine, we cannot but admire the genius of those who, from the crude and shapeless ore, have produced such marvels of ingenuity and skill.

Expatiating on the uses of this important metal, Dr. Ure says, "Iron accommodates itself to all our wants, our desires,

and even our caprices; it is equally serviceable to the arts, the sciences, to agriculture, and to war; the same ore furnishes the sword, the ploughshare, the scythe, the pruning-hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon and the bomb. It is a medicine of much virtue, and is the only metal friendly to the human frame." To this we may add, it supplies our rail and tramways, our ships, our steam boilers and engines, and in great part our dynamo-electric machines, from which we obtain our electric light; it also forms our bridges, our lamp-posts, our telegraph wires, and the pipes which convey our water and gas.

*Early History of the Uses of Iron.*—Although there have been many differences of opinion as to when the so-called Iron Age commenced, there can be no doubt whatever that this metal was employed for various useful purposes even so early as the sixth generation from the creation of the world, for we read in the 4th chapter of Genesis, v. 22, that Tubal-cain was "an instructor of every artificer in brass and iron." In Daniel ii. 40, occurs this passage: "Iron breaketh in pieces and subdueth all things," and mention is made, not only of iron as a metal, but also of its being applied to many useful purposes, both peaceful and warlike, in many other passages in the Old and New Testaments.

Mr. Watson, in his "Biblical and Theological Dictionary," observes: "The knowledge of working it was very ancient; we do not, however, find that Moses made use of iron in the fabric of the tabernacle in the wilderness, or Solomon in any part of the temple at Jerusalem. Yet, from the manner in which the Jewish legislator speaks of iron, the metal, it appears, must have been in use in Egypt before his time. He celebrates the great hardness of it in Levit. xxvi. 19; Deut. xxviii. 23, 48;

takes notice that the bedstead of Og, King of Bashan, was of iron, Deut. iii. 11; he speaks of mines of iron, Deut. viii. 9; and he compares the severity of the servitude of the Israelites in Egypt to the heat of a furnace for melting iron, Deut. iv. 20. We find, also, that swords, Numb. xxxv. 16: axes, Deut. xix. 5, and tools for cutting stones, Deut. xxvii. 5, were made of iron. By the 'northern iron,' Jer. xv. 12, we may probably understand the hardened Iron called in Greek χάλυψ, from the Chalybes, a people bordering on the Euxine Sea, and consequently lying on the north of Judea, by whom the art of tempering steel is said to have been discovered. Strabo speaks of this people by the name Chalybes, but afterwards Chaldæi, and mentions their mines."

Regarding the knowledge and employment of Iron by the Egyptians, the Rev. Basil Cooper remarks:—"It must, I think, be conceded that, supposing Iron to have been known to the Egyptians, its employment in the construction of those Titanic erections, the Pyramids, is far more probable than the hypothesis that none but bronze tools were used, and this, I think, can be satisfactorily demonstrated.

"The proof is based on the extremely significant Coptic word for Iron, as illustrated and explained by the mode in which it is written in the hieroglyphical inscriptions, and on the occurrence of that word as a componant element in the name of an Egyptian Pharoah belonging to the dynasty. The modern Egyptian word for Iron is, in the Sahidic dialect, which is considered to be the purest, *Benipi*, or with a slight change in the final vowel *Benipe*. In the hieroglyphical form of the language it is the same.

"Its first element is B A or B E (in the Coptic B O) meaning 'hardwood or stone;' and the two letters which spell the word are often accompanied in the hieroglyphical

inscriptions by a picture of the squared stone, such as those of which the Pyramids are built. At other times, as if to remind us that the word originally meant 'hardwood,' and that it was only in process of time that it came to denote '*hardware*' in general, including such stoneware as was going in very early times, the picture illustrating the *spelt* word was a branch or sprig. The middle syllable in the word *Benipe* consists of the letters N I, with a very short vowel. It is a preposition, answering to the English 'of.' The last element in the composite word is the syllable P E, which is the Coptic word for heaven, or the sky. And that this is really its signification here is proved incontrovertibly by the pictures with which this syllable is wont to be accompanied in the hieroglyphical orthography of the word *Benipe;* for it is the picture invariably used to denote the heaven or the sky and is employed for no other purpose. Properly it represents the ceiling of a temple, which was regarded as itself a representation of the sky, the true ceiling of the true and original temple, and the picture is accordingly wont to be emblazoned with stars. Hence," says Mr. Cooper, "the signification of the entire word *Benipe,* although it could not for some time be conceived why the Egyptians should have called Iron by so singular a name as 'stone of heaven,' 'stone of the sky,' 'sky stone.'

"Sometime afterwards, however, it occurred to me that this was the very name which would naturally be given to the only iron with which men were likely to meet in a natural state. There is but one exception to the rule that iron is never found native like gold and some other of the metals; that exception is in the instance of *meteoric iron,* which might surely be called with propriety 'the stone of heaven or of the sky.' Moreover, and I have to thank my friend Mr. Pengelly

for reminding me of the fact, and so naturally helping me to shape out my crude speculation—meteoric iron needs no preparatory process, as does that procured from ores, to render it workable. In short we may be sure, especially with the light thrown on the matter by the invaluable Egyptian word, bright with the radiance of that heaven which enters into its composition, that with this wondrous matter from another sphere than our own the working of Iron began."

The theory that meteoric iron was used by the Egyptians, the Israelites, or other invaders of Egypt, for making tools for cutting stone, is to our mind far more satisfactory than that which suggests the employment of either bronze or stone implements in the building of such colossal structures as the Pyramids. Indeed, it seems almost incredible that the hieroglyphic figures of animals, trees, and other objects of deification could have been so well executed with tools of bronze or stone.

In Mr. Day's exhaustive treatise on the "Prehistoric Uses of Iron and Steel,"* the author remarks :—"To turn again to the question of the priority of Iron, how does the investigation result? Not, as we should expect, according to the Stone, Bronze, and Iron succession doctrine, but precisely the reverse of that; for not only are iron instruments depicted in the tomb pictures of the fourth dynasty at Memphis itself; among the monuments there Iron has been found, and is now in this country of ours. Not only is metallic iron found in that very locality, but, remarkably so, it has been found in the very oldest building there—and by the universal record of all who are competent to judge, the very oldest building in the whole earth; not in that particular building either in such a way as to have been placed there by

* "Prehistoric Uses of Iron and Steel," by St. John V. Day.

accident or intention, at a time subsequent to the erection, but in such a way as that it could have been placed there when, and only when, the structure was in course of erection. It may perhaps appear startling to be told that, after a plate of malleable Iron was removed by blasting it out from the solid masonry of the Great Pyramid by Colonel Howard Vyse, thirty-nine years ago, and which has been ever since deposited in the British Museum, we have altogether failed to meet with an allusion to it by any writer of the history of metallurgy, whilst by the Egyptologists, although confessedly well-known to some of them, its existence has never been referred to, until notice was first directed to it by the writer in 1871. This piece of iron to which we refer was not dug up amongst any rubbish or concrete mass of matter at the foundations of the Pyramid which have there accumulated, but was obtained out of the solid masonry at the top of the building, as the following passage and certificates quoted from Howard Vyse's 'Pyramids of Egypt' testify :—

"Mr. Hill discovered a piece of Iron in an *inner* joint, near the mouth of the southern air-channel which is probably the oldest piece of Wrought Iron known. It has been sent to the British Museum with the following certificates :—'This is to certify that the piece of iron found by me near the mouth of the air-passage in the southern side of the Great Pyramid of Egypt, on Friday, May 26th, was taken out by me from the *inner* joint, after having been removed *by blasting the two outer tiers of the stones* of the present surface of the Pyramid; and that no joint or opening of any sort was connected with the above-mentioned joint, by which the iron could have been placed in it after the original building of the Pyramid. I also showed the exact spot to Mr. Perring, on Saturday, June 24th.

"J. R. HILL.

"CAIRO, *June 25th*, 1837."

"To the above certificate of Mr. Hill I can add that since I saw the spot at the commencement of the blasting, there have been two tiers of stone removed, and that if the piece of iron was found in the joint pointed out to me by Mr. Hill, and which was covered by a large stone, partly remaining, it is impossible it could have been placed there since the building of the Pyramid. "J. T. PERRING.

"CAIRO, *June 27th*, 1837."

"We hereby certify that we examined the place whence the iron in question was taken by Mr. Hill, and we are of opinion that the iron must have been left in the joint during the building of the Pyramid, and that it could not have been inserted afterwards. "ED. S. ANDREWS.

"JAMES MASH, C.E."

There can be no doubt whatever that, owing to the extreme oxidizability of Iron, any implements fabricated from this metal thousands, or even hundreds of years ago, would, unless protected from atmospheric influence in some way, be converted into oxide of iron, by which all traces of its form, or even its existence, would be lost for ever to human observation. That iron *had* been used almost in the earliest period of man's existence upon our earth is clearly established in the first Book of Moses, as we have shown, and if we do not *now* find relics of such extreme antiquity, at least Mr. Layard's researches have proved beyond doubt that the Assyrians employed this metal for many useful purposes nearly a thousand years before the Christian era.

Respecting the early use of Iron, Dr. Percy observes:—"That the Assyrians were well acquainted with Iron is clearly established by the explorations of Mr. Layard, who has enriched the collection of the British Museum with many objects of iron

from Nineveh of the highest interest. Among these may be mentioned tools employed for the most ordinary purposes, such as picks, hammers, knives, and saws. There is a saw similar in construction to that now used by carpenters for sawing large pieces of timber across. It was found in the North-west Palace at Nimroud, and it is computed that, while it could not date later than 880 B.C., it may have been considerably earlier.

"Among the ancient Greeks bronze evidently preceded iron, but many passages in Homer show that iron was common in his time, and that even the art of tempering iron by plunging it into cold water was well known. The Romans were early acquainted with the art of extracting iron, and carried it out on a very large scale. They carried the art with them into the countries which they conquered, and Spain, Elba, and other localities attest the magnitude of their operations by the vastness of the *debris* which they left behind, in the shape of cinders from their furnaces," &c.

The Romans, who were far behind the Carthagenians in respect to their navy, having no knowledge of ship-building, suffered greatly from the depredations of the Carthagenian fleet; being a determined and resolute people, however, they resolved to possess themselves of an efficient fleet, to which end Fortune favoured them by the stranding of a Carthagenian galley, from the design of which they built their first fleet. Their vessels, however, not being sufficiently effective against their more powerful foes, the Romans constructed a destructive machine called the *Corvus*, which was made after the following fashion: "They erected on the prow of their vessels a round piece of timber, of about one foot and a half in diameter, and about twelve feet long; on the top whereof they had a block, or pulley. Round this piece of timber they had a stage or platform of boards, four feet broad, and about eighteen feet long,

which was well framed and fastened with *iron.* The entrance was longways, and it moved about the aforesaid piece of timber as on a spindle, and could be hoisted up within six feet of the top. About this there was a sort of parapet, knee-high, which was defended with *up-right bars of iron, sharpened at each end,* towards the top whereof there was a ring. Through this ring, fastening a rope, by the help of the pulley, they hoisted or lowered the engine at pleasure, and so with it attacked the enemy's vessels, sometimes on their bow and sometimes on their broadside as occasion best served. When they had grappled the enemy with these *iron spikes,* if they happened to swing broadside to broadside, then they entered from all parts; but in case they attacked them on the bow, they entered, two and two, by the help of this machine, the foremost defending the forepart, and those that followed the flanks, keeping the boss of their bucklers level with the top of the parapet."*

The above is from Polybius' account of the first warlike preparations which the Romans made by sea. It will be noticed that their famous offensive and defensive machine owed its effectiveness to *spikes of iron.* The Romans are also said to have used slings or thongs, which were loaded with lead or iron.

According to the Greek poets, Iron was not only known, but extensively used in their own time, but the remarkable discoveries of Dr. Schliemann, Mr. Day thinks, tend to throw considerable doubt upon their accuracy. Rather than discredit these sublime writers, however, we should be more disposed to believe that any Iron implements made in their day, and still more such as *may* have existed in ancient Greece, had perished by the slow, but sure, process of oxidation.

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* Kennett's "Antiquities of Rome."

Mr. Day makes the following observations upon this subject, which will be read with interest:—"Yet whilst Greek poets so wrote, it would now appear to be in direct antagonism to facts belonging to the period immediately preceding the times in which they flourished, if even they were not quite within their own ken, for the recent memorable researches of Dr. Schliemann* into the Hill of Hissarlik, in the Troad—whether he has really succeeded in disentombing the Ilion of Homer or not—indicate that he has dug down far enough to get at hard facts, and to have found relics, with every appearance of probability, belonging to a time preceding the establishment there of a Lydian dominion, or at the lowest estimate, about 1400 B.C., and extending thenceforward over a period of at least 1700 years.

"Dr. Schliemann has found the superposed foundations of no less than four successive cities, but notably has not met with a progress, from a lower to a higher order of things, in any sense whatever. The city which he—and that with extremely strong evidence in his favour has pronounced to be Troy, of which Priam was King, being the second from the bottom (that a still older city) with the Palace, Treasure, Tower, wall, and a double scœan gate, of which Homer has sung, still extant. The construction of the overlying cities is progressively inferior, until terminating in the Greek colonists, who had ceased to cut and dress stone, building their houses of wood. . . . . If we then interrogate Dr. Schliemann on the evidence respecting the Stone, Bronze, and Iron Ages, he tells us at once that the theory is all assumption, and not borne out by a single fact or relic to be met with in the Hill of Hissarlik, for there in the ruins of every city he finds knives, hatchets, and arrow-heads of flint,

* "Troy, and Its Remains," by Dr. Henry Schliemann.

diorite, and a very hard transparent green stone, by thousands, in immediate contact with thousands of ornaments and articles of utility, formed not only of copper and bronze, but of gold also; and while in the older deposits neither Iron nor Steel have been met with in the metallic state, yet certain relics, which have somewhat dubiously been denominated sling-bullets of Iron, in a state of oxide, were found in them, side by side with flint, copper, and bronze instruments. Tin was also absent, although mentioned by Homer; but Iron relics, still metallic, were found in the uppermost deposits."

Dr. Schliemann's English editor remarks, "Such facts as these furnish a caution against a too hasty application of the theory of the Ages of Stone, Bronze, and Iron."

## CHAPTER II.

**Mineralogy of Iron—Pure Native Iron—Native Nickeliferous Iron, or Meteoric Iron—Native Steel Iron—Magnetite—Titaniferous Iron Sand—Iron-glance, or Specular Iron Ore—Sulphides of Iron—Red Oxide of Iron—Brown Oxide of Iron—Compact Carbonate of Iron, &c.**

PURE NATIVE IRON is exceedingly rare, and, except in a few isolated instances, is generally believed to be of meteoric origin (see page 23). Iron chiefly occurs in combination with oxygen (oxides of iron), sulphur (sulphides of iron), or combined with acids in the form of salts, as carbonate, sulphate, chromate of iron, &c. It is one of the most widely-diffused

products of our earth, being present, in some form or other, in every part of the globe, permeating every soil, existing even in vegetables, and in the blood of the higher order of animals, the red colour of which is due to the presence of iron. The brilliant red colour of coral* is due to a trace of peroxide of iron, and the beautiful veins and markings of the various marbles are also chiefly produced by oxides of iron; indeed, there are comparatively few substances in nature with which this metal is not either directly or indirectly associated.

Iron ores abound in all parts of the earth, and in every mineral formation, and that country which is most favoured by its presence, and that of its grand associate—Coal—from their transcendant importance to mankind, becomes the richest and most powerful country in the world. Such has been, and still is, England's proud position. May she long retain it!

The ores of Iron are the following:—

*Pure Native Iron.*—The extreme rarity of Iron in a pure state, led many naturalists to doubt its being a natural product of our globe; and in presence of the fact that masses of iron had frequently been known to descend upon our planet—but from whence none can tell—such scepticism would not be unreasonable. The pure metal, however, is said to have been found in volcanic formations, in some grains of platinum ores from the Uralian mines, and also in veins; and it is assumed that such examples are evidence of its terrestrial origin. By mineralogists it is regarded chiefly as a curiosity. Pure Native Iron is whiter and more ductile than wrought-iron (which is nearly pure, containing never more than 0·25 per cent. of carbon) and is not so readily oxidized in the air. Its

* The formation of corals is described in the author's "History of a Lump of Chalk," p. 17, &c.

colour is of a bluish-grey, and when broken it presents a fibrous texture.

*Native Nickeliferous Iron*, or *Meteoric Iron* is, as its latter title indicates, an *accidental* product of the earth and not "native" in the ordinary sense. The consideration of meteoric stones, or aërolites, is reserved for a separate chapter, to which the reader is referred. Meteoric Iron contains from 1 to 20 per cent. of nickel, and it is a remarkable fact that this metal is always present in meteoric stones.*

*Native Steel Iron.*—The existence of *Steel* as a natural product (which is of very rare occurrence), may also be considered accidental, if we reflect upon the circumstances connected with its discovery. It is said that M. Mossier found this Native Steel at the village of Boniche, near Nery, department of the Allier, in a spot *where there had existed a seam of burning coal.* The presence of Carbon being absolutely necessary to the formation of Steel—which is a *chemical* compound of iron and carbon—the production of the native steel above mentioned is thus readily accounted for. The specimen referred to weighed 16 lb. 6 oz., and a considerable number of small globules were also found at the same place.

*Magnetite, Black Oxide of Iron, Magnetic Iron Ore or Loadstone.*—This remarkable ore, of which we shall have to speak hereafter, possesses the power of attracting iron or steel—sometimes in a wonderful degree. It is believed to have been first discovered in Magnesia, a town in Asia Minor. The Greeks are believed to have given the name "Magnes" to this mineral, from which we have taken our English term *magnet.*

Magnetic Iron Ore is found largely in Sweden, Norway,

* Which fact warrants the belief that they have a common origin, whatever that may be.

China, Siberia, and some other localities, but is very rarely met with in England. In Sweden it occurs in massive beds, at Arendahl and Dannemora, and is extensively worked for the production of Iron, which is famous for its excellent quality, being perfectly free from sulphur and phosphorus.

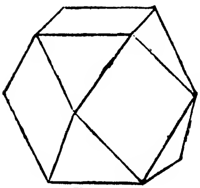

Fig. 1.

Magnetic iron ore is a compound of two oxides of iron, namely, the protoxide and the sesquioxide. One hundred parts of the ore contain 31 per cent. protoxide, and 69 per cent. sesquioxide, with an inconsiderable proportion of silica. It is sometimes crystalline, as in fig. 1.

*The Titaniferous Iron Sand* found at Taranaki, in New Zealand, in India, and elsewhere, is of the same composition as the above, with the addition of another metal, Titanium, which occurs in the sand in considerable quantity. This sand furnishes excellent steel. This mineral is also attractable by the magnet.

*Iron Glance, Specular Iron Ore, Red Iron Ore,* or *fer oligiste,* is a crystalline ore (see figs. 2, 3, 4, 5) containing usually from 60 to

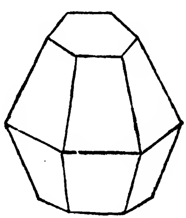

Fig. 2.—Elba.

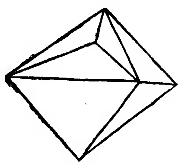

Fig. 3.—Elba.

70 per cent. of metallic iron.; it has the colour of polished steel and is so hard as to scratch glass. It occurs in great abundance in the Island of Elba, whose mines are famous for the great

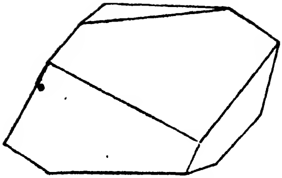

Fig. 4.—Vesuvius.

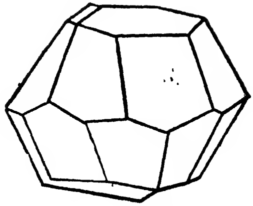

Fig. 5.—Framont.

antiquity of their workings. Ure says, "It exists in very great masses, constituting even entire mountains; in the cavities and fissures of these masses, the beautiful crystals so much prized by collectors of minerals occur. The ore of Antenna is a very hard compact *fer oligiste*, of a beautiful metallic aspect. The workable bed has a height of 66 ft., and consists of metalliferous blocks mixed confusedly with sterile masses of rock, the whole covered with a rocky detritus (disintegrated matter) under a brownish mould. From its metallic appearance and toughness, this bed is called *vena ferrata*, the iron vein. In Pietamonte the workable bed is composed entirely of micaceous specular iron ore (*fer oligiste*), with its fissures filled with yellow ochre. This bed rests upon the rock called *bianchetta;* the brilliant aspect of ore in this place has gained for it the name of *vena lucciola*. . . . The varieties called specular *fer ogiliste* and scaly *fer oligiste*, or Iron Glance, do not differ essentially from the compact. None of them affect the magnetic needle, and their powder is of a red of greater or less vivacity."

The compact varieties of specular iron ore, also occur in Corsica, Saxony, Bohemia, Sweden, &c.

*Sulphides or Sulphurets of Iron.*—These ores are not used for the production of iron, but, being rich in sulphur, are employed for extracting that useful substance for various uses in the arts.

*Yellow Sulphide of Iron*, or *Iron Pyrites*, occurs in all veins of

metallic ores, and is frequently the only mineral that forms the veins in quartz. Both gold and silver have been found in Iron Pyrites. It occurs in crystals of great beauty (see figs. 6, 7), of a

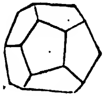

Fig. 6.

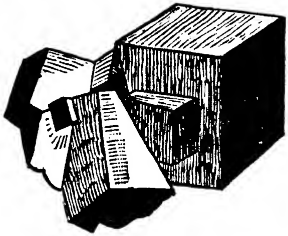

Fig. 7.

brass-yellow colour, and is very brittle. When heated it gives off its sulphur very freely, as we may often have noticed when burning coal impregnated with it. The yellow crystalline veins which are so often observed in our household coal, consist of sulphide of iron, and when burnt, reddish-brown lumps appear in the cinders, called *crocus*, which is the sesquioxide of iron that remains after the sulphur has been driven off during the combustion of the coal in the grate. *White Sulphide of Iron* is distinguished from the former by its colour and the difference of its form of crystallization (fig. 8). *Magnetic Sulphide of Iron* is attractable by the magnet, like ordinary iron, hence the Germans call it *magnetkies.* It is of a yellowish red colour, and contains sixteen parts of sulphur and twenty-eight parts of iron.

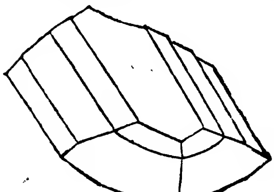

Fig. 8.

*Red Oxide of Iron, Sesquioxide of Iron,* or *Hematite.*—This mineral, which is represented by the illustration on the cover of this work, is an exceedingly abundant Oxide of Iron, and was doubtless the source from which Iron was obtained in the early days when charcoal alone was used as fuel in the operations of

smelting. It occurs in several different conditions, is of a brown-red colour, and more or less soft. The ore contains a large percentage of the sesquioxide of iron, mixed with silica and small quantities of carbonate of lime. It is frequently known, in certain districts, in Bristol, for example, by the name of *redding*. When reduced to a powder, and washed with water to separate the oxide from its coarser particles, it is used as a common red pigment, and is specially adapted for coating iron-work. The crystallized variety of this mineral (see figs. 9, 10) contains 70 per cent. of Iron and 30 per cent. of

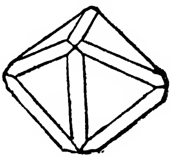

Fig. 9.

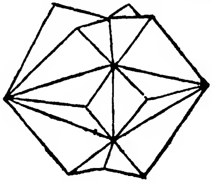

Fig. 10.

Oxygen. The harder kind of hæmatite may be polished, when it assumes almost a metallic lustre. Sometimes its outer surface is in a concrete form, of excessive hardness, which is known by the name of *bloodstone,* and this is used for making burnishing tools for brightening or burnishing the surfaces of silver and plated goods. The softer hæmatite is frequently termed *red iron ochre.*

*Brown Oxide of Iron,* when reduced to powder, is of a yellow and sometimes brownish colour. If calcined at a red heat, the ore yields a red powder. The yellow and brown oxides always contain some water in their composition; hence they are frequently termed *hydrated* oxides of iron.

"The *ætites,* or eagle-stones," says Dr. Ure, "form a particular variety of this ore. On breaking the balls so named, they are observed to be composed of concentric coats, the outside ones being very hard, but the interior becoming progressively

softer towards the centre, which is usually earthy and of a yellow colour; sometimes, however, the centre is quite empty, or contains only a few drops of water. Ætites occur in abundance, often in continuous beds, in secondary mountains, and in certain argillaceous strata. These stones are still considered by the French shepherds as amulets or talismans, and may be found in small bags which they suspend to the necks of their favourite rams; and they are in such general use that a large quantity is annually imported into France from the frontiers of Germany for this superstitious purpose."

*Granular Brown Oxide*, or *Bone Ore*, is only a variety of the above, occurring in small roundish grains, which also are composed of concentric layers, hard outside and soft within, and these grains are sometimes cemented together by a calcareous or clayey paste, or otherwise in loose granules. This ore is found in calcareous formations, and is occasionally associated with shells, as the *terebratulæ*, for example. *Bog Iron Ore* and *Morass Iron Ore* are of this species of Brown Iron Ore.

*Native Carbonate of Iron, Spathose*, or *Sparry Ore, Siderite*, or *Brown Spar*.—This valuable mineral is classified into two varieties—namely, *Spathic Iron* and *Compact Carbonate*. The former, or sparry variety, belongs to the primary formations, and occurs in extensive veins in mountains of gneiss,* in the Alps of Savoy, in Styria, Carinthia, in the Tyrol, in Saxony, Germany, Spain, and Sweden. It also occurs associated with *galena* and other lead ores in the mines of Scotland, in Cumberland, Derbyshire, Cornwall, and other districts in England. It is an important characteristic of this valuable iron ore that it

* *Gneiss*, in geology, is a term applied to rocks which, unlike mica-schist (which is mainly composed of quartz and mica), consist of quartz, felspar, and mica.

produces *natural steel* with the greatest facility. It was formerly called *Steel Ore.* When moderately heated, spathic iron becomes attractable by the magnet.

The principal ore from which iron is smelted in England and Scotland is the Carbonate of Iron of the coal measures, which generally yields from 30 to 33 per cent. of cast-iron. The ore in one mine near Glasgow yielded 41·26 per cent. of metal.

*Compact Carbonate of Iron,* or *Clay Iron-Stone,* is the chief source of Iron in England, and occurs in great abundance in the coal measures of Dudley, in Staffordshire; in the coalfields of Monmouthshire, South Wales; as also in Gloucester and Somerset. Compact carbonate of iron differs greatly from spathic iron ore in its physical characteristics. The ore is of a yellowish-brown or reddish-grey brick-red colour, is close grained, and, being largely mixed with argillaceous, or clayey, matter, it adheres to the tongue when touched by it. Clay iron-stones occur in rounded masses of varied proportions in the slaty clay which serves as roof or floor to the strata of coal, also in beds from 2 to 18 in. in thickness among the coal measures in Staffordshire, &c. The coal basins of Newcastle contain but little clay Ironstone, while the coal basin of Dudley abounds with it.

Fig. 11.

Fossil remains of animals and plants have frequently been found in the Ironstone nodules. The accompanying illustration (fig. 11) from Dr. Mantell's delightful work, "The Wonders of Geology," represents a fossil species of *Limulus,* or king-crab, discovered in the iron-stone of Coalbrook Dale.

In Dudley the ore occurs asso-

ciated with coal and limestone, which latter is used as a flux in the smelting operations. At Merthyr Tydvil, in Wales, the Ironstone is very abundant, occurring in beds of slate, clay, or *shale*, in which it assumes a great variety of forms, being sometimes in stratified veins or in nodules, or rounded lumps, of various sizes and shapes, in layers both above and below the coal seam.

One variety of clay iron-stone is mixed up with a large quantity of carbonaceous matter, and is termed "black band," owing to its glossy black colour. "Clay band" ironstone is generally of a bluish-grey colour, both varieties occurring more or less in most coal formations. They are, however, of special importance in Scotland, Warwickshire, Staffordshire, South Yorkshire, and South Wales. The comparatively recent discovery of an impure carbonate of iron in the lias of Yorkshire has given rise to the largest pig-iron producing district in the world—namely, that of Cleveland—the development of which has taken place at a marvellously rapid rate; indeed, in the year 1876 it had reached the enormous sum of over 2,000,000 tons for one year's produce!

*Pitchy Iron Ore* is a very rare mineral, possessing a resinous appearance. It consists of red oxide of iron and water. Hence it is also called *pitchy hydrate of iron.*

*Yenite* is also a somewhat rare mineral, the composition of which is red oxide of iron, silica, and lime.

*Arsenical Iron*, or *Mispickel*, is a tin-white mineral containing, besides metallic iron and arsenic, varying proportions of sulphur, and, occasionally, silver. When heated it yields the peculiar odour of garlic characteristic of the vapour of arsenic.

*Native Phosphate of Iron* is of a dull blue colour, and occurs in small masses, sometimes in aggregated plates, or otherwise in a fine powder, imparting to contiguous objects its blue tint.

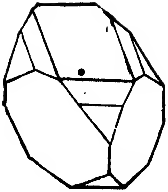

Fig. 12.

*Native Sulphate of Iron, Green Vitriol,* or *Green Copperas.*—This occurs by the action of the oxygen of the air upon native sulphuret of Iron, when pale green crystals (see fig. 12) of sulphate of iron are formed, which are soluble in water. When heated the crystals first give up their water of crystallization, and by increasing the heat to bright redness the sulphuric acid becomes expelled, when a bright red powder remains, which is peroxide of iron. In this way jewellers' rouge (which is pure peroxide of iron) is sometimes made.

*Chromate of Iron,* or *Chrome Ore.*—This important mineral is found near Baltimore, in Maryland, U.S., in small quantities in France, in the Shetland Isles, in Banffshire, and also in Silesia and Bohemia. The ore has a slightly metallic lustre, and is of a brownish-black colour. Its composition, according to the analysis of one specimen, was :—Oxide of chromium (its metallic base), 43; protoxide of iron, 34·7; alumina, 20·3; and silica, 2, in 100 parts. The principal use of this valuable mineral is in the manufacture of *chromate* and *bichromate* of *potash.* The ore is first cleansed from earthy matters surrounding it, and after a while it is ground in a mill and sifted. The powder is then mixed with one-third of its weight of nitre, and the mixture submitted to a powerful furnace heat for several hours. The calcined matter is then removed from the furnace, and when cool, is lixiviated with water. A bright yellow solution is thus obtained, which is evaporated briskly, and a bright lemon-yellow salt (*chromate* of potash) deposits, which is then removed and allowed to drain. This salt, again dissolved in a small quantity of water, is converted into *bichromate* of potash, by adding to the concentrated solution sulphuric acid or muriatic acid, and this solution on being slowly evaporated and allowed to repose,

yields beautiful bright red crystals of bichromate of potash, a substance much used in the arts.

*Arseniate of Iron* occurs native in the mineral called *Wurfelerz.* The *per* arseniate of iron also occurs native as "iron-sinter."

*Carburet of Iron.*—The substance known as *plumbago, graphite,* or *black-lead* is chiefly composed of carbon, combined with a small percentage of iron. Its most important sources are the mines of Cumberland, where it is obtained in abundance.

*Oxalate of Iron,* or *Humboldtite,* so called after its illustrious discoverer, Baron Humboldt, has been found in the lignite of Kolaw. Its composition is: protoxide of iron, 53·86; oxalic acid, 46·14, in 100 parts.

*Titanite of Iron* is composed of protoxide and peroxide of iron, titanic acid, and manganese, associated with a small percentage of earthy matter.

*Emery.*—This mineral, which was formerly considered to be an iron ore, was examined by the late Mr. Tennant, who found it to be composed of alumina, 80; silica, 3; and iron, 4 parts. It occurs abundantly at Cape *Emeri,* Isle of Naxos, and also in Jersey and Guernsey, in Poland, Saxony, Sweden, &c.; from its extreme hardness it is much used for grinding various metals, glass, some of the softer precious stones, &c.

The various substances called *ochres,* as Yellow Ochre, Brown Ochre, Terra di Sienna, Venetian red, and Umber, consist of oxides of iron mingled with clay and earthy matters. When calcined at a moderate heat, their colour becomes altered, and it was doubtless in this way that many shades of colour were produced by the old masters.

## CHAPTER III.

### Native Iron—Meteorites, or Aërolites—Theories concerning their Origin—Their Chemical Composition.

*Native Iron*—that is, *pure* iron—is exceedingly rare, and is believed by many to be of meteoric origin. Ure, however, says, "It has been undoubtedly found not only in volcanic formations, but in veins properly so called," and Brande states that Iron in a state approaching purity is found among the grains of platinum from the Uralian mines, and a thin vein of it is said to have been discovered in chlorite slate near Canaan, in the United States of America. The term *native iron* is, however, generally applied to the masses of Meteoric Iron which have, from time to time, fallen upon our earth, but why these strange visitors should be honoured with the title "native" it is difficult to understand, although the term is generally applied.

The origin of Meteoric Stones has been the subject of much speculation. At one time they were supposed to have been ejected, or thrown up from air volcanoes, but their chemical composition does not admit such a theory. Others believed that they may have been discharged, by volcanic disturbance, from the moon,* but is it not equally probable that the meteoric

* "The notion that these bodies came from the moon is, when impartially considered, neither absurd nor impossible, for any power that would move a body 6000 feet in a second, that is about three times the velocity of a cannon ball, would throw it from the sphere of the moon's attraction to that of our earth. The cause of this projectile force may be a volcano, and if thus expelled, the body would reach us in about two days, and enter our atmosphere with a velocity of about

matter has been, and is still constantly being produced in infinite space, and finally reaches our earth by the force of her attraction? From whatever source they come, these ponderable masses must add to the original weight of our globe, and although the aggregate weight of those meteoric stones which have fallen upon the higher portions of the earth's crust may—although considerable—be comparatively insignificant, yet how vast may have been the quantity deposited in the depths of the ocean of which we can know nothing!

Speaking of the meteorites which fall upon our earth, Dr. Mantell quotes the following observations of the gifted Mrs. Somerville: "That ornament and pride of her sex," says the great geologist, "has the following interesting remarks on this subject:*—'So numerous are the objects which meet our view in the heavens, that we cannot imagine a part of space where some light would not strike the eye: innumerable stars—thousands of double and multiple systems—clusters in one blaze with their ten thousands of stars—and the nebulæ amazing us by the strangeness of their forms; till at last, from the imperfection of our senses, even these thin and airy phantoms vanish in the distance. If such remote bodies shone by reflected light, we should be unconscious of their existence; each star must then be a sun, and may be presumed to have its system of planets, satellites, and comets, like our own; and for aught we know, myriads of bodies may be wandering in space, unseen by us, of whose nature we can form no idea, and still

25,000 feet in a second. Their ignition may be accounted for either by supposing the heat generated by their motion in our atmosphere sufficient to ignite them, or by considering them combustible, and ignited by contact of air."—*Brande*.

* "Connection of the Physical Sciences," p. 423.

less of the part they perform in the economy of the universe. Nor is this an unwarranted presumption: many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence to the earth. The fall of meteoric stones is much more frequent than is generally believed: hardly a year passes without some instances occurring; and if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall into the ocean, or on the uninhabited parts of the land, unseen by man. They are sometimes of great magnitude: the volume of several has exceeded that of the planet Ceres, which is about seventy miles in diameter. One which passed within twenty-five miles of us was estimated to weigh about *six hundred thousand tons,* and to move with a velocity of about twenty miles in a second—a fragment of it alone reached the earth. The obliquity of the descent of meteorites, the peculiar substances of which they are composed, and the explosion attending their fall, show that they are foreign to our planet. Luminous spots, altogether independent of the phases, have been seen on the dark parts of the moon; these appear to be the light arising from the eruption of volcanoes; whence it has been supposed that meteorites have been projected from the moon by the impetus of volcanic eruption. If a stone were projected from the moon in a vertical line with an initial velocity of 10,992 ft. in a second—a velocity but four times that of a ball when first discharged from a cannon—instead of falling back to the moon by the attraction of gravity, it would come within the sphere of the earth's attraction, and revolve around it like a satellite. These bodies, impelled either by the direction of the primitive impulse, or by the disturbing action of the sun, might ultimately penetrate the earth's atmosphere and arrive at its

surface. But from whatever source meteoric stones may come, it is highly probable that they have a common origin, from the uniformity, we may almost say identity, of their chemical composition."

Van Hoff, in an admirable essay on the origin of meteoric stone, observes that although it is demonstrated mathematically that aërolites and masses of native iron which fall from the air *may* be derived from the moon, yet the weight of evidence is in favour of their being nebulous matter suddenly condensed, and which descends to this planet's surface when this mysterious process takes place within the sphere of the earth's attraction. These masses present a general correspondence in their structure and appearance, having (with the exception of native iron) a crystalline character internally, and a black, shaggy crust externally.—*Dr. Mantell.*

The nebulous theory is to our mind far more satisfactory than the hypothesis of the moon throwing stones at us! And when it is borne in mind that astronomers are frequently discovering *new planets*, may we not conjecture that these also are formed, and being constantly produced, from nebulous matter in the illimitable space beyond our planet?

The fact that nickel is *invariably* associated with iron in meteoric stones, although in varying proportions, irresistibly leads to the conclusion that these bodies have a common origin, whether they are the products of other planets, of one planet only, or have been developed in space by natural laws of which we are at present ignorant, or at most have but an imperfect idea. That these stones are not of volcanic origin—that is to say, have not been ejected from any of our own volcanoes—is clearly established by the very nature of their composition, which in no respect accords with the character of terrestrial volcanic matter.

While treating of this interesting subject, we may direct the reader's attention to the numerous specimens of meteoric stones in the Mineralogical Department of the Natural History Museum, South Kensington, some of which have been cut and polished to show their internal structure. One fine specimen, from Melbourne, weighing three and a half tons, is in a separate glass-case, while numerous smaller specimens, from various countries, are carefully arranged in other cases, the whole forming an exceedingly interesting collection of these remarkable foreign—not native—bodies.

The following account of a meteoric stone is given, in *The American Journal of Science,* by one who witnessed its fall, and which cannot fail to prove interesting, inasmuch as it explains, and very clearly, the phenomena attending the visit of the remarkable stranger.

"On the 10th of February, between the hours of twelve and one o'clock, I heard an explosion—as I supposed—of a cannon, but somewhat sharper. I immediately advanced, with a quick step, about twenty paces, when my attention was arrested by a buzzing noise, as if something was rushing over my head, and in a few seconds I heard something fall. The time which elapsed from my first hearing the explosion to the falling might have been fifteen seconds. I then went with some of my servants to find where it had fallen, but did not at first succeed; however, in a short time the place was found by my cook, who dug down to it, and a stone was discovered about two feet below the surface. It was sensibly warm, and had a sulphurous smell; was of an oblong shape, and weighed sixteen pounds and seven ounces. It has a hard vitreous surface.* I

* Meteoric stones are generally covered with a varnish-like glaze which protects them from oxidation.

have conversed with many persons, living over an extent of fifty miles square; some heard the explosion, while others heard only the subsequent whizzing noise in the air; all agree in stating that the noise appeared directly over their heads. The day was perfectly fine and clear. There was but one report heard, and but one stone fell, to my knowledge; there was no peculiar smell in the air; it fell within 250 yards of my house." An analysis of this aërolite gave the following results:—

| | |
|---|---|
| Oxide of iron . . . . . . . | 24 |
| ,, nickel . . . . . . | 1·25 |
| Silica, with earthy matter . . . | 3·46 |
| Sulphur, a trace | |
| | 28·71 |

Meteorites have been found in almost every part of the world, and in masses weighing from a few ounces each up to thirty tons or even more, while others have been observed in their transit through space, which have been estimated at a probable weight of many hundred thousands of tons, but which did not come within the sphere of the earth's attraction. A brief reference to a few of the most remarkable meteorites will, it is hoped, prove interesting, since each of them (allowing for its nickel and other minor associates) presents the appearance of a veritable Lump of Iron.

A mass of meteoric iron was discovered in 1772 by Professor Pallas on the summit of a mountain between Abakansk and Belskoi Ostrog, in Siluria, which weighed 1600 lbs. Another mass, found in Peru, weighed 15 tons. In the year 1751 a meteoric stone was seen to fall in Croatia; it was said to have resembled a large globe of fire. This is preserved in the Imperial Museum of Vienna. The following account of the fall of a meteorite at Ensisheim, near Basle, upon the Rhine,

is deposited in the church, and bears date "A.D. 1492, Wednesday, November 7th, there was a loud clap of thunder,* and a child saw a stone fall from heaven: it struck into a field of wheat, and did no harm but made a hole there. The noise it made was heard at Lucerne, Villing, and other places. On Monday, King Maximilian ordered it to be brought to the castle, and, after having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade anyone to take anything from it. He, however, took two pieces himself, and sent another to Duke Segismund of Austria." This stone weighed 225 lb. The above is believed to be the first reliable account of the fall of a meteoric stone.

The once celebrated Yorkshire stone, which was seen to fall by a ploughman and two other persons, on December 13th, 1795, near Major Topham's residence, at Thwing, East Riding of that County, was at once dug out of the hole in which it had buried itself. This stone is in the Natural History Museum; its weight is 56 lb.

In 1672 a meteoric stone fell near Verona, which weighed 300 lb. On July 3rd, 1753, stones fell simultaneously at Plann, Stokow, and some other places in Bohemia, one of which, containing a great proportion of attractable iron, is to be seen in the Museum at South Kensington. In 1768 three stones fell in different parts of France; and in 1790 there was a perfect shower of these meteorites, near Agin, which was witnessed by Darcet and several other persons. In 1783 a mass of meteoric iron was found by Don Rubin de Celis, at

* The so-called clap of thunder was doubtless the sound caused by the explosion which frequently occurs when these stones approach our earth.

Otumpa, South America, who estimated its weight at about 15 tons. A large mass of iron, supposed to be a portion of the above, was presented to the British Museum by Sir Humphry Davy and Sir Woodbine Parish.

Should the reader, after perusing these pages, happen to pay a visit to the Natural History Museum, he cannot fail to be gratified by a view of the very interesting collection of Meteoric Stones there deposited and most carefully arranged.

## CHAPTER IV.

### Cast-Iron, How formerly Made—Substitution of Coal for Charcoal in Smelting Iron.

As to the date of the invention of cast-iron there is some doubt. It appears, however, to have been manufactured and worked in the fourteenth century, since there is a slab of cast-iron in Burwash Church, Surrey, which dates from this period, with an ornamental cross and the following inscription :—

"Pray for the soul of John Collins."

About the commencement of the fifteenth century, Agricola wrote, "Iron smelted from ironstone is easily fusible, and can be tapped off." In the year 1543 Ralph Hoge, or Hogge, appears to have made cannons from cast-iron, employing a Frenchman as his assistant, and also one Thomas Jennings. The son of a servant of the former is stated to have made, in or about 1595, "42 pieces of great ordnance of iron for the Earl of Cumberland, weighing 6000 lb., or 3 tons, a piece."

It appears that at this time the manufacture of iron in some parts of England had become so extensive and, consequently, the consumption of timber for making charcoal (the only fuel then used for this purpose) so great, that the number of iron-works had to be limited by Acts of Parliament. In the year 1584—the twenty-seventh of Queen Elizabeth's reign—an Act was passed to check the wholesale destruction of timber which was taking place in the counties of Sussex, Surrey, and Kent. The terms of this Act were as follows:—"Whereas by our great negligence, or number of iron-works which have been, and yet are, in the wealds of the counties of Sussex, Surrey, and Kent, it is thought that the great quantities of timber which hath been grown in those parts hath been greatly spoiled and wasted, and in a short time will be utterly consumed, if some remedy be not provided, and it is therefore enacted that no person, from and after the feast of Easter next, shall erect in any place within the said counties any manner of iron-mills, furnace, finery, blomary, for the working or making of iron or iron metal, other than either upon such old and former leazes or pens whereupon hath lately been or at the time of the new erection shall be then standing some iron-mills, furnace, or hammer, or else in or upon such lands as the party so erecting any such new intended works shall continually furnish the same with a sufficient supply of wood, standing and growing upon their own proper soil, or land being to him or them fee simple," &c.

*Substitution of Coal for Charcoal in Smelting Iron.*—Up to this period, and for long afterwards, the only fuel used in Iron Manufacture was wood charcoal, and it was not until the year 1611 that a substitute for this fuel was found by Simon Sturtevant, to whom a patent was granted for the use of "sea coale or pit coale" in the manufacture. Whether he was successful in

working his process is not quite clear, but one Dad Dudley, who had been experimenting in the same direction, published, in 1665, his "Metallum Martis, or Iron made with Pit Coale, and to him the credit of having developed the smelting of iron with *coked* coal is generally given. Those who follow the originator of an idea generally get the most credit, and frequently also the reward. Dudley's process having died with him, the new system was eventually worked out by Abraham Darby, of the Coalbrook Dale Works, about 1735, and the smelting of iron with coke as fuel largely increased the production of pig-iron from this time.

The introduction of coke for smelting iron was followed by an improvement in blast furnaces—namely, a cylinder blowing machine with reciprocating pistons, as a substitute for the single bellows previously used—whereby a considerable increase in the yield of pig-iron was effected, and the production of Malleable Iron also facilitated, which up to this time had been effected by melting it on an open hearth partly filled with fuel, and exposing the iron to the oxidizing influence of a blast of air. The metal was thus partially deprived of its carbon, and afterwards the pasty mass was removed with tongs, hammered, reheated and again hammered, until it assumed the form of bars. This tedious process, which was varied in different localities, was afterwards substituted by a far more effective system, devised and patented by Henry Cort in 1783, which consisted in employing grooved rolls for rolling the metal instead of hammering. In 1784 Cort patented his process for *puddling*, as it is termed, and, although these important inventions were of inestimable benefit to mankind, he became a ruined man at last, a fate too commonly the reward of merit in this country. It appears that Cort's partner, Adam Jellicoe, deputy-paymaster of the Navy, had defrauded the Government to the extent of

£27,000, and to recover this, in whole or part, Cort's patent rights and property were confiscated, and the poor fellow was thus cruelly, hopelessly ruined, although it was subsequently proved that, had the royalties under his patent been properly collected, they would have been sufficient to have paid the amount of his partner's defalcations six times over! Probably no Government ever stained its country's reputation by a worse act than this. Although to Henry Cort was unquestionably due the merit of practically developing the *puddling process*, it was originated by George and Thomas Cranage, of Coalbrook Dale, who patented a similar process in 1766—that is, eighteen years prior to Cort's patent. This is another instance of one sowing and another reaping, but in this case not the *second* patentee, but his Government, did the reaping!

The old-fashioned blast-furnace has undergone many improvements from time to time, the most important of which was Beaumont Neilson's application of a *hot blast* to promote the fusion of iron in place of the cold blast previously used, by which great economy of fuel was effected, and the process of smelting considerably hastened. The further consideration of Cast-Iron Manufacture will form the subject of the next chapter.

## CHAPTER V.

**Manufacture of Cast-Iron—The Blast-furnace—Hot-blast Stoves—Preparation of the Ore for Smelting—Coking the Coal—Charging the Furnace.**

THE operation of *Smelting*, or reducing iron ores to the metallic state, is conducted in large furnaces, which are called *blast-furnaces*, because, during the process of smelting, currents of air are driven into the furnace by means of powerful blowing machines. In early times, when charcoal was the only fuel used for smelting the brown and red oxides of iron, a rude kind of wooden bellows was employed for this purpose. This contrivance was superseded by the introduction of the cylinder blowing machines, with double pistons, by which a continuous stream of air was obtained. As evidence of the vast importance of the cylinder machines, and the substitution of coke for wood charcoal as fuel, the following data will doubtless prove interesting. Up to the year 1740 wood charcoal was, with one or two exceptions, the only fuel used in smelting iron, and at this period the annual produce of iron was about 17,000 tons. From that period, and up to 1788, when the employment of coke was becoming more generally developed, and the cylinder blowing machines adopted, the production of iron steadily increased, and in this latter year rose to 61,000 tons. In 1796 the use of charcoal was almost entirely abandoned, and the product rose to 124,849 tons; in 1802 it had reached 170,000 tons; in 1820, 400,000, and in 1826 the product was 600,000 tons. Thirty years after, namely in 1856, the produce was

3,586,377, and in 1880 no less than **7,749,233** tons. So that in less than twenty-five years the enormous production of 1856, as it was considered to be at the time, was more than doubled!

These remarkable figures are interesting as showing how England's most important manufacture progressively increased under the new conditions of fuel and blowing apparatus. We may venture to say that if some substitute for charcoal had not been found, either the Manufacture of Iron must have been greatly limited, or by this time there would scarcely have been left a full-grown tree upon our island.

*The Blast-furnace.*—Blast-furnaces, although constructed more or less upon the same principle, are variously designed in the different districts in which they are employed. There have been considerable modifications in the size of blast-furnaces during the present century, with a view to increase the productive power per furnace, and to effect a saving in the consumption of fuel. Neilson's discovery of the effect of *heating* the blast before it enters the furnace—causing thereby much economy in fuel—has led to continual increase of temperature of the blast, until, at the present time, it is frequently used *red-hot.* For heating the blast a separate apparatus is employed, called a *stove,* and the construction of these blast-stoves has been so repeatedly improved upon from time to time that they now occupy more space and are nearly as costly as the furnaces themselves.

The following description of a blast-furnace, from the pen of an able writer,* will show the reader how this leading piece of mechanism in the art of Iron Manufacture is formed, and how much skill and scientific thought must have been bestowed upon it construction :—

* Tomlinson's "Cyclopædia of Arts."

"The blast-furnace (fig. 13) consists of two truncated cones, *a*, *b*, united at their bases. The upper part, called the *cone* or *body*,

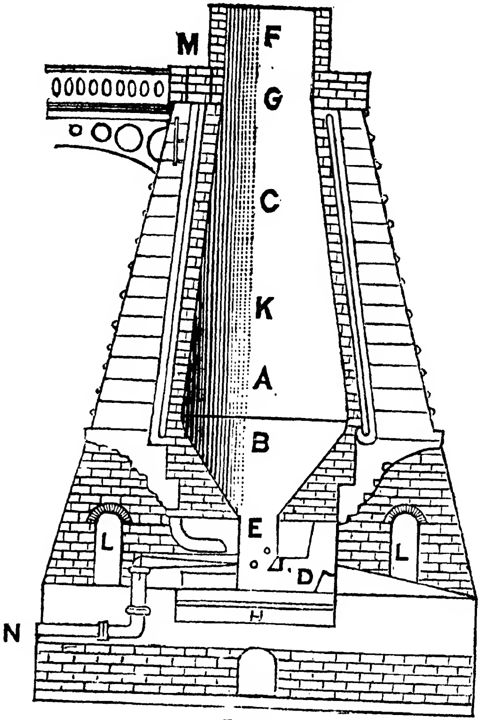


Fig. 13.

is formed by an interior lining, or *shirt*, of firebricks; there is another lining of fire bricks, the space between the two being filled up with broken scoriæ or refractory sand. The outer casing of firebricks is supported by a thick wall of masonry or brick, and this is strongly bound on the outside by stout iron bands connected by long vertical bars, whereby great strength and solidity is given to the building. The exterior casing is also traversed

by numerous channels, to allow of the escape of moisture from the masonry or brick-work, since any pent up steam might lead to the destruction of the furnace. At the top of the furnace is an opening, *g*, called the *throat*, and above this is the chimney, *f*, in which are openings, *m*, which, with the throat, are used for pouring in the charges of fuel, ore, and flux. The lower cone, *b*, called the *boshes*, is formed of firebrick or firestone, and requires the greatest care in its construction, for upon its durability depends the continued operations of the furnace. To prevent the formation of an acute angle at the junction of the cones forming the body of the boshes, the edges are slightly rounded off by the introduction of a narrow belt, whereby a space is formed called the *belly*. The lowest division, *e*, called the *hearth*, is nearly quadrangular in form; it is constructed with large slabs of refractory sandstone cemented with fireclay. It is somewhat smaller at the bottom than at the top point where it meets the boshes, and its angles are gradually rounded off. The bottom of the furnace is formed of a large firestone supported by a mass of masonry, *h*, in which are various channels left open for the escape of moisture from the brickwork, and to keep the whole structure dry; the foundations are traversed by two large vaults, *ll*, which intersect each other just below the axis of the furnace.

"Three of the sides of the hearth are continued down to the large firestone; the fourth side, *d*, is carried down to a certain distance, where it is supported by strong cast-iron bearers let into the masonry of the walls, which also support a heavy block of sandstone called *tymp*. Below this, at a distance of five or six inches, and a little in advance of it is the *damstone*, prismatic in form, secured on its outer side by a piece of cast-iron called the *dam*-plate. The part of the furnace below the tymp is called the *crucible*, and in it is collected the fused metal reduced

by the operations of the furnace. The three continuous faces of the hearth are perforated a little above the level of the tymp with holes for receiving the nozzles of tuyeres (or twyers), *n*, which convey the blast from the blowing machine into the furnace."

At some old works the furnaces are erected against a steep bank, so that the materials (ore, fuel and flux) can be wheeled from the various *depôts* on the bank direct to the furnace tops, but at most modern works a method of hoisting is adopted. This generally consists of an inclined railway extending to the mouth of the furnace, round which a platform is fixed, and which is railed around for the safety of the workmen. The trucks containing the material are raised and lowered by ropes working over a drum set in motion by steam power.

*Hot-blast Stoves.*—Directly connected with the blast-furnace is the apparatus for heating the air before it enters the furnace. There are two forms of such *hot-blast stoves*, as they are termed. The first is a cast-iron stove, in which the blast is heated by passing through a series of iron-pipes kept at a dull-red heat either by means of a coal-fire, or by burning the waste gases of the blast-furnace. A more recent form of blast-stove is made from firebrick, the modification being an adaptation by Cowper of Siemens' regeneration principle, and this again has been improved upon by Whitwell. In the construction of this stove several air-tight chambers are lined with firebrick, and there is an arrangement of loose firebrick in the interior by which the gases burnt at one point give up most of their heat to the brick-work before they leave the chamber. When the brickwork has become sufficiently heated, the gas is stopped off, and the blast admitted in such a way that before leaving the stove it has passed over the hot brickwork and become raised to the required temperature. While one stove is being cooled down by heating the blast, the other stove is being heated up, to be in turn

cooled down. In the cast-iron stove the heat can only be limited because the iron pipes soon become destroyed if the heat be too severe. About 1000° Fahr. is reckoned a good heat from these stoves; but with those constructed from firebrick the temperature may be raised to from 1500° to 1600° Fahr.

There are several forms of engine employed to give the necessary pressure to the hot blast, namely the reciprocating beam engine, the grasshopper engine and the vertical engine. In the beam engine, a heavy beam, moved by the piston rod of a steam cylinder on one side, moves the piston of a large cylinder on the other side, in which the blast is raised to the required pressure. In the grasshopper engine, the beam is supported at one end by a vibrating arm, and at the other end is joined to the piston rods of the steam and blast cylinders, the two cylinders being in line with the beam. The vertical engine is largely used in the Middlesborough district. The beam is dispensed with, the two cylinders are placed vertically, one above the other, and the piston rods are made continuous. In other forms of this engine, the cylinders are placed side by side, and the piston rods joined by a cross-head.

*Preparation of the Ore for Smelting.*—The principal ore used in this country for producing Iron, being the Native Carbonate of Iron called *Clay Ironstone,* it is to the treatment of this mineral that we must chiefly turn our attention. The ore is first subjected to a process termed *roasting*, the object of which is to deprive it of water and carbonic acid, by which operation it generally loses from 23 to 30 per cent. in weight, and the roasted ore produces from 30 to 33 per cent. of *pig-iron.* The ordinary method of roasting the ironstone is to place it in heaps, with layers of coal. The ground is first levelled, then a layer of coal about six to eight inches deep is spread over a portion of the surface,

into the opening in the *throat* of the furnace, and the supply is constantly kept up so as to keep the furnace always full. In a furnace of moderate dimensions, there will be thrown into it 14½ tons of coke, 16 tons of roasted ore, and 6½ tons of limestone, as a *flux*;* and from these proportions about 7 tons of pig-iron are obtained. The molten metal is run off at the hole beneath the *crucible*, about every twelve hours, at which period, in some establishments, the blast is stopped. The metal to be converted into bar-iron, or to be again cast into moulds, is run into small pigs 3 ft. long and 4 in. in diameter, each pig weighing about 2½ cwt.

## CHAPTER VI.

### Manufacture of Wrought-Iron from Pig-Iron—The Refining Process—The Puddling Process—Forging the Iron into Bar-Iron.

CAST-IRON, as it comes from the furnace, is largely impregnated with carbon and silicon, and also contains small quantities of sulphur and phosphorus. To eliminate these impurities—the absence of which is absolutely necessary to good malleable iron—the crude cast-iron is subjected to two consecutive processes of purification. The first process, commonly called the *fining* or *refining* process (and formerly *finary*), is conducted in a low-built furnace of brickwork, in the centre of which is the *smelting*

* Any substance which promotes the melting of another is called a *flux*.

*hearth.* In this the grey cast-iron is first fused—by the action of numerous *tuyeres*—and then suddenly cooled, by which *white cast-iron*, or *fine metal* is produced, to be afterwards further refined by what is termed the *puddling process.*

*The Refining Process.*—In this process, the hearth is first filled with coke, then a row of cast-iron pigs is laid horizontally on the hearth, and these are covered with a quantity of coke. The fire is then lighted, and about a quarter of an hour after, the blast is turned on. After a while the cast-iron begins to flow, and collects in the crucible of the furnace, when additions of coke and pigs are made until the whole metal becomes liquid, which generally occupies about two hours.

The tap-hole is now opened, and the "fine metal" allowed to flow out, with the slag, into a flat mould. A large quantity of water is then poured on the metal, which renders it brittle, and being thus suddenly cooled, it is very white, and has a fibrous texture. The metal is afterwards broken up into fragments, and is then weighed to ascertain the amount of product of each operation. The fine metal, being thus deprived of the uncombined carbon associated with it when it came from the smelting furnace, is not only considerably whiter, but is also more homogeneous; by the refining process also, a greater portion of its silicon is removed, which runs off with the slag.

*The Puddling Process.*—This important refining operation is conducted in a reverberatory furnace,* and much of the success and economy of the process depend upon the skill and judgment of the workmen, called *puddlers,* who conduct the operation. The puddling furnace is charged with the fragments of metal of the last operation, by means of a shovel, the pieces being laid

* A low-built furnace, in which the flame from the fuel is chiefly confined to the hearth, where most heat is required.

over one another on the sides of the hearth, forming piles reaching nearly to the roof of the furnace, the middle being left open for the puddling metal as it becomes fused. The lumps of metal are kept as separate as possible, to allow a free circulation of air round the piles. The working-door of the furnace is now closed, fuel laid on the grate, and the mouth of the fire-place, as also the side opening of the grate, are filled up with coal, and the damper then opened.

"The fine metal, in about twenty minutes, comes to a white heat, and its thin-edged fragments begin to melt and fall in, drops on the side of the furnace. At this time, the workman opens the small hole of the furnace-door, detaches with a rake the pieces of fine metal that begin to melt, tries to expose new surfaces to the action of the heat, and in order to prevent the metal from running together as it softens, he removes it from the vicinity of the fire-bridge. When the whole of the fine metal has thus got reduced to a pasty condition, he must lower the temperature of the furnace, to prevent it from becoming more fluid. He closes the damper, takes out a portion of the fire, and the ribs of the grate, and also throws a little water sometimes on the semi-fused mass. He then works about with his paddle the clotty metal, which swells up, with the discharge of gaseous oxide of carbon, burning with a blue flame, as if the bath were on fire. The metal becomes finer by degrees, and less fusible; or in the language of the workmen, it begins to get *dry*. The disengagement of carbonic oxide diminishes, and soon stops. The workmen continue meanwhile to puddle the metal till the whole charge be reduced to the state of incoherent sand; and at that time the ribs of the grate are replaced, the fire is restored, and the register is progressively opened up. With the return of the heat, the particles of metal begin to agglutinate, the charge becomes more difficult to raise, or in the

labourers' language, it *works heavy*. The refining is now finished, and nothing remains but to gather the iron into balls. The founder, with his paddle, takes now a little lump of metal, as a nucleus, and makes it roll about on the surface of the furnace, so as to collect more metal, and form a ball of about 60 or 70 lbs. weight. With a kind of rake, called in England a *dolly*, and which he heats beforehand, the workman sets this ball on that side of the furnace most exposed to the action of heat, in order to unite its different particles; which he then squeezes together, to force out the scoriæ. When all the balls are fashioned (they take about twenty minutes' work), the small opening of the working-door is closed with a brick, to cause the heat to rise, and to facilitate the welding. Each ball is then lifted out, either with tongs, if roughing rollers are to be used, as in Wales, or with an iron rod welded to the lump as a handle, if the hammer is to be employed, as in Staffordshire. Thus we see that the operation lasts in whole from 2 to 2½ hours; in a quarter of an hour the fine metal melts at its edges, when the puddling begins, in order to effect its division; at the end of an hour or an hour and a half, the metal is entirely reduced to a sand, a state that is kept up for half an hour, by continual stirring; and finally the balling operation takes nearly the same time."—*Ure.**

By the above treatment of the cast-iron, in the refining and puddling furnaces, the metal has been almost entirely freed from the carbon and silicon (or *silicium*) with which it was associated in the crude state, by the oxidizing influences of heat and blasts of air. Oxide of iron is formed during the process, which the carbon reduces to the metallic state, while a portion of the carbon escapes in the gaseous state, as carbonic oxide.

* "Dictionary of Arts, Manufactures," &c.

The silicon during the reaction becomes converted into *silicic acid*, which, uniting with a portion of the oxide of iron, forms a fusible silicate of iron which unites with the slag. By these continued reactions the crude metal becomes converted into a spongy mass of *malleable iron*, and a fusible slag, which latter is afterwards separated from the iron by pressure, or by powerful hammering. Small quantities of sulphur and phosphorus are generally present in pig-iron, and it is absolutely necessary that these should be removed during the refining, since their presence, even in minute proportions, destroys the valuable properties of wrought-iron. When these substances are known to be present in the ore, they should be removed by careful roasting, but when the sulphur is derived from iron pyrites in the fuel during the smelting process, carbonate of lime should be added, which converts the sulphur into sulphide of calcium, which passes off with the slags. Phosphorus may also be eliminated in the same way. Ores, however, which contain large proportions of sulphur or phosphorus, never produce good malleable iron.*

The balls are removed from the puddling furnace by means of heavy tongs, or by the iron rod called a "porter," welded to each ball, and are conveyed to the *helve* or *shingling* hammer, or to the squeezer,† either of which machines (which are worked by steam power) presses or squeezes out the *slag*, causing the hot metal to become more homogeneous and *condensed*. The *slab* thus produced is afterwards subjected to the *roughing rolls*. In former times the metal had to be heated and hammered alternately, and repeatedly, to bring about the condensation, and consequent toughness, so essential to good malleable iron.

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* "Chemistry as Applied to the Arts and Manufactures."

† Sometimes Nasmyth's powerful steam-hammer has been used for this purpose.

*Forging the Iron into Bar-iron.*—The machines used for the purposes of forging and drawing out the iron into bars, are cast-iron hammers of great weight, and cylinders of various dimensions; the former being used for beating out the balls formed in the puddling furnace, and the latter for extending them into bars. Very powerful steam shears are also employed for cutting the iron bars, the pressure from which is so great that they can cut bars of considerable thickness. In hammering out the "bloom," or rough ball from the puddling furnace, it is laid on the anvil of the machine and turned about upon it by the iron rod welded to it (the "porter"), until it acquires a shape suitable for the *roughing rolls* or cylinders. Sometimes the balls are taken direct from the puddling furnace to the roughing rolls.

The roughing cylinders are about 7 ft. long and 18 in. in diameter, and weigh about 4 or 5 tons; sometimes, however, they are considerably larger. The cylinders have a series of grooves, some of which are of an elliptical form, and others square—each groove being progressively smaller than the other. When the bar is transferred from one groove to the next, or smaller groove, it becomes extended in every direction. The iron bar delivered from the square grooves is afterwards cut by the shears into short lengths, which are formed into a bundle, and welded together in a reheating furnace; as soon as the bundle of bars becomes hot enough the pieces adhere together, when the bundle is conveyed to the rollers to be again extended into bar iron.

In cylinder drawing, one workman, holding the ball in the tongs, passes it into the first elliptical groove, and a second man on the other side of the cylinder receives the lump and hands it over to the first, who again passes it through the rollers, previously giving a turn to the pressure

screws which bring the rollers closer together. After passing several times through the same groove, the lump is shifted to the next smaller groove, which causes it to become considerably lengthened; this is next subjected to another pair of cylinders, by which it is drawn into flat bars of various widths according to the purpose for which it is required. This is called *puddled bar*, or *mill-bar iron*, having a very rugged appearance, and requires further welding to strengthen it before it is applicable to machinery purposes; it is first cut, while still hot, into lengths of 3 or 4ft., according to the size of bar required, by means of powerful shears. These lengths are placed in piles of six or seven in the reheating furnace, and again heated until they stick together, when they are taken in successive piles to the bar-drawing cylinders, which convert them into "No. 2" iron, or bar of medium quality. When iron of very tough quality is required, an extra welding and rolling is given. If what is called "merchant iron" is required, the bars are usually 5 or 6 in. wide, and three-quarters of an inch thick; for plates, the bars are made from 12 to 16 in. wide and 1½ in. in thickness. When plates are to be manufactured, the puddled bar slabs are used for the top and bottom of the piles, the shearings from previously rolled plates placed between them, and the whole heated, and afterwards rolled into a finished plate.

It will be seen that in the manufacture of Wrought-Iron, the alternate processes of reheating and subsequent compression—whether by means of the hammer or the powerful cylinders—imparts to the metal that characteristic toughness or malleability which is so essential for the many purposes to which this useful form of manufactured iron is applied.

The *shingling mill* and plate-rolling mill are ordinarily combined in one series, the whole being set in motion by a very powerful steam engine. The former, as we have seen, is

employed for converting the *bloom* from the puddling-furnace (after squeezing or hammering) into *bar iron*, and the latter, which are hard, smooth rollers, or cylinders, for rolling the iron into plates or hoops. Each roller is kept cool by a stream of water.

"One of the most simple plans" of making Malleable Iron from Cast-Iron, "though one of the latest in chronological order, consists in embedding the cast-iron in powdered oxide of iron, and subjecting the whole to a moderate, but long-continued heat; this process is somewhat similar in character, though reverse in its action, to the old cementation process for making steel. The plan is not applicable to large quantities of the material, or to large masses, but it is much used for making what are called *malleable castings*. The small castings are embedded with oxide of iron, in cast-iron chests, and six or eight of these chests are placed in the furnace; sometimes they are placed in a reverberatory furnace; a better plan is to place them on a rotating bed. They are kept at a bright red heat for five or six days, and then gradually cooled."—*Chemistry as Applied to the Arts, &c.*

## CHAPTER VII.

### Ironfounding—The Patterns—Moulding in Green Sand—Moulding in Baked Sand—Moulding in Loam—Melting the Cast-Iron.

WHEN we consider the vast magnitude of the operations which constitute the Ironfounder's business and the endless

variety of forms which Pig-Iron, under his treatment, assumes, it becomes apparent that in the space of a few pages only a brief outline of the general system of founding could be attempted.

The founder classifies the Cast-Iron with which he has to deal as follows:—No. 1, or best grey, which, possessing a larger proportion of carbon than any other variety of Iron, melts at the lowest degree of heat. It exhibits a smooth surface in castings, and produces but little sound when struck by the hammer. No. 2, of a lighter grey colour, is neither so soft nor so fluid when melted as the former, nor are castings from it so smooth on the surface; it is, however, closer in texture, and more suitable for strong parts of machinery. No. 3 contains less carbon than the two former, is still less fluid when fused, has a finer grain and presents a smooth fracture. It is employed for castings of very powerful machinery, such as is subjected to very great strains, as heavy shafts, wheels, &c. No. 4 closely resembles No. 3, but is not much used in foundry work; neither is No. 5, or *White Iron*, or *silver iron*, as it is sometimes termed, which cannot be run into the moulds, being difficult to keep in a state of fusion. In white iron the carbon is said to be *combined*, whereas in the other varieties it exists in the form of *graphite*, mechanically diffused throughout the mass.

The *Pattern*, or object to be reproduced in Cast-Iron, is usually made of wood, the operation of pattern making being conducted by skilled workmen in a light workshop, specially devoted to this purpose. Sometimes the patterns are made of metal, or consist of metal castings which are required to be reproduced. From these patterns *moulds* have to be taken, which are made with what is called *green sand*—that is, sand as it comes direct from the pit—mixed with a little powdered coal; *baked sand*, or sand that has been used before, and *loam*.

*Moulding in Green Sand.*—A mixture of pit sand with about one-twelfth of its bulk of coal dust is worked up with a little water so as to form a porous mass which will readily take and retain an impression of the pattern. This mixture is only used once for the finer castings, and is afterwards employed either for inferior castings or for filling up the bottoms of fresh moulds. For making the moulds, two square iron frames are used, which, when fitted together, form a box or case, without bottom or lid, for holding the mould. Each half of this box exactly corresponds with the other, and they are united by points which project from one of them fitting into the holes drilled in the other; when thus adjusted they are fastened by cross pins or wedges and secured by bolts.

When making a mould, one of the frames is laid upon the foundry floor, and this is filled with green sand by means of a shovel, and the sand is lightly pressed with an iron *punner* or rammer until a perfectly uniform surface is prepared. Upon this the pattern is laid, and a gentle pressure given so as to partially imbed it in the sand. The pattern is then covered with sand, and, after clearing away any sand that may have fallen upon the edges of the frame the second frame is put over it, and this is next filled with the green sand. The box is now inverted, whereby the first half becomes uppermost. This is next carefully lifted, and carries with it the body of sand first formed in it. The pattern remains imbedded in the sand of the second half, having been exactly moulded upon its surface. The moulder now sprinkles a little water over the sand nearest the mould, so as to condense it, and he then trims all irregularities with small iron trowels of various forms; he next dusts a little finely-sifted sand over the visible surface of the pattern, and the sand surrounding it, to prevent adhesion, when the first frame is replaced. He then breaks up the preparatory smooth bed

formed in the second frame, covers the pattern with green sand, and replaces the first frame, which he then fills with sand and rams it tightly. The two frames being separated, the pattern is carefully removed and one or more channels are scooped out of the sand in the first frame, for the passage of the molten metal, and also another channel for the escape of air. When the mould is of considerable size, the metal is run into several channels at the same time. The box being securely fastened and weighted, the molten metal is then run in.

In moulding in *baked sand,* or sand that has been used before, the mechanical arrangement is the same as for green sand, but when the mould is prepared, it is conveyed to the drying stove, where it is allowed to remain from 12 to 24 hours, or until it is deprived of all moisture. The mould is then said to be *annealed.* It is not usual to mix powdered coal with this moulding material.

*Moulding in Loam* is performed in quite a different way to the preceding, inasmuch as the moulds are made from *drawings,* instead of from patterns, whereby the expense of making the latter is saved. The moulds are formed by certain mechanical contrivances, from a pasty composition consisting of clay, sand, water, and cows' hair, the materials being worked up, or kneaded, in what is termed a *loam-mill.* When made, the mould is thoroughly dried before the melted metal is poured into it.

As an example of the system of mould-making from a design or drawing, the following description of the method of making a mould for cast-iron pans or coppers (or, as the Americans call them, kettles), such as are used by tallow-melters, sugar-boilers, and others, described in a recent work,* will show how

* "American Foundry Practice." By Thomas D. West.

mechanical ingenuity has overcome the necessity for a pattern in making this kind of mould :—

"The bottom plate (see fig. 14) rests solid on three or four

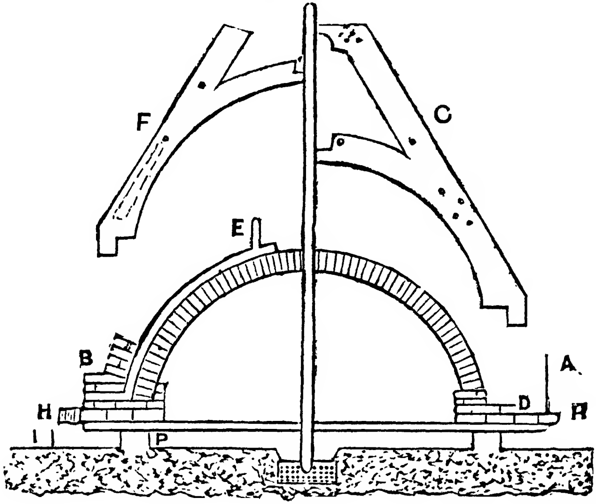


Fig. 14.

blocks, as shown at *p*; the inside sweep (or mould) is attached to the spindle, at the level joint *d*; the top of the flange and the inside of the kettle is bricked and 'swept up.' After the loam has become stiff and hard, the outside sweep, *f*, is attached, and a thickness is swept up, on which the flange outside the kettle is formed. This thickness is generally formed with green sand, keeping the sweep up, so as to sweep from one-sixteenth to one-eighth thicker than the casting required. This gives the required thickness when the sand is 'slicked.' Over this slicked surface a coat of clay wash is brushed and dried hard, thus making a solid surface to build against. To form a joint between the thickness and outside, oil and parting-sand are used. Sometimes, instead of keeping the sweep up, to allow

slicking and clay washing over the surface, the sweep is set to give the thickness wanted, and after the green sand thickness is roughly swept up, a third coat of loam is swept upon the green sand, thereby forming a smooth surface.

"There is not much trouble in sweeping up a plain surface thickness on loam moulds with green sand, but where there are flanges or projections, it requires time and patience. It is a good plan, for instance, instead of sweeping up the flange thickness with green sand, to form it with pieces of brick and loam. In some instances this plan is adopted. Sometimes wooden segments are used to form the flange of the kettle. After putting on the thickness, the joint is cleaned off, and oiled, and parting-sand sprinkled over it, after the outside lifting ring *hh* is set on, and the outside of the mould is bricked up, as from *l*. After the thickness has been swept up, the spindle is hoisted out, and the *hole* firmly bricked up. The outside being bricked up, it is then hoisted off by the four handles, *h*. The thickness is then taken off, and the mould finished up and put in the oven, or dried on the floor.

"In getting ready to cast, a sheet-iron curbing is set around the outside of the mould, and sand rammed between it and the brickwork, the same as in similar loam moulds. After this sand has been rammed about six inches above the top of the brickwork, a flat plate is bedded on and wedged or held down by the use of an iron cross, and slings hitched to it and the four handles of the bottom plate. When ramming this sand care must be used, as it is not like ramming up a plain vertical loam mould. The pounding of the rammer should be lighter the higher up it is used; in fact, the upper parts do not require ramming. The lower part of the mould should be rammed solid and hard, as there is considerable strain there."

*Melting the Cast-Iron* is performed in what is termed a *cupola*

furnace, which is a blast-furnace furnished with a series of holes, one above another, which are progressively opened from below upwards to receive the blast from the blowing machine as the cast-iron melts.

The furnace being kindled, it is filled up to its throat with coke, and soon after the tuyere blast is set in action, and when the coke sinks in the furnace, alternate charges of coke and pig-iron, broken into pieces weighing about 14 lb., are given, and in about twenty minutes after the metal begins to melt, when further charges are given about every ten minutes, each charge (according to the size of the furnace) consisting of from 2 cwt. to 5 cwt. of metal. It is estimated that about 200 lb. weight of coke will melt 1 ton of pig-iron after the cupola-furnace has acquired its proper heat. The proportions of fuel are, however, regulated according to the qualtity of iron required for the castings.

When very large castings are required, the moulds are frequently sunk in the ground of the foundry, in which case the molten metal is run direct from the furnace to the mould. For this purpose a channel is made in the floor of the foundry, through which the fused metal flows until the moulds are full. For casting smaller work, the melted metal is carried in cast iron pots or ladles, lined with loam, each pot, according to its size and weight, being carried by two or more men.

When the moulds have cooled, they are taken asunder and the casting examined. All superfluous metal on the edges is then broken away with a hammer, and when quite cold it is further trimmed with hammer and cold chisel.

## CHAPTER VIII.

### Miscellaneous Improvements in the Iron Industries.

AMONGST the numerous improvements connected with Iron, which have, during the present century, conferred incalculable benefit upon mankind, may be mentioned those which relate to the manufacture of nails. Up to fifty years ago nails were made solely by hand, being hammered or forged from malleable iron. Since then, the old-fashioned "tenpenny nail" and its congeners has given way to machine-made nails of endless variety and marvellous cheapness. The credit of producing the first nails made by machinery, and termed "cut nails," is due to our American cousins, as will be seen from the following extract from a report of the Secretary of the State of Massachusetts, published many years since:—"Twenty years ago some men, then unknown, and then in obscurity, began by cutting slices out of old hoops, and by a common vice griping these pieces, headed them with several strokes of the hammer. By progressive improvements, slitting mills were built, and the shears and the heading tools were perfected; yet much labour and expense were requisite to make nails. In a little time Jacob Perkins, Jonathan Ellis, and a few others, put into execution the thought of cutting and heading nails by water power; but being more intent upon their machinery than upon their pecuniary affairs, they were unable to prosecute the business. At different times other men have spent fortunes in improvements, and it may be said with truth that more than one million of dollars has been expended, but at length these joint efforts are crowned with complete success, and we are now able to manufacture, at

about one-third of the expense that wrought-iron nails can be manufactured for, nails which are superior to them for at least three-fourths of the purposes to which nails are applied, and and for most of these purposes they are full as good.

"To northern carpenters it is well known that in almost all instances it is unnecessary to bore a hole before driving a cut nail; all that is requisite is to place the cutting edge of the nail across the grain of the wood; it is also true that cut nails will hold better in the wood. These qualities are, in some rough building works, worth 20 per cent. of the value of the article, which is equal to the whole expense of manufacturing. For sheathing and drawing, cut nails are fully as good as wrought nails; only in one respect are the best wrought nails superior to cut nails, and that is where it is necessary they should be clinched."

Subsequent to this statement, a great number of patents were taken out in this country for making nails, many of which were of American origin, and at the present time the manufacture of nails by machinery in this country alone has assumed proportions which are truly marvellous.

Another and most important improvement in nails, of French origin, is the elegant wire nail (*pointes de Paris*), also machine made, which has, for many purposes—for putting together packing-cases, for example—greatly superseded even the cut nail. The great advantage of these wire nails is that they can be driven into any soft wood without the use of the bradawl, and without in any degree splitting the timber—a fault from which even cut nails are not always exempt.

Hooks and eyes, and even pins, which were formerly made only from brass wire, are now frequently made from iron wire —a fact which may readily be determined by applying a magnet, which of course will not attract them if they are made of brass.

exposure to the air. This is prussian-blue. If the *perchloride of iron* be used instead of the sulphate, the characteristic blue colour is produced at once. Ferrocyanide of potassium is also largely used in dyeing and calico-printing.

*Sulphate of Iron or Copperas.*—When dilute sulphuric acid is poured upon iron filings, the metal becomes dissolved, with the evolution of hydrogen gas, and a pale green solution is formed which, by evaporation and subsequent cooling, yields crystals of a delicate sea-green colour. Native sulphide of iron (Iron pyrites), exposed to moisture and the air, attracts oxygen from the latter, and becomes converted into *sulphate* of iron. The copperas of commerce is usually prepared from the pyritous schists of the coal measures, in connection with the manufacture of alum. The aluminous schists frequently abound in iron pyrites, and the two products, copperas and alum, are obtained by calcination and subsequent lixiviation (dissolving out the soluble ingredients) of the minerals. The schists are calcined in heaps, by which the sulphur of the iron ore absorbs oxygen from the air, which converts it into sulphuric acid. This acid combines with the iron and alumina of the schist, forming sulphate of iron and sulphate of alumina (alum). These salts are dissolved out of the calcined minerals, and the solution thus obtained is afterwards evaporated in large cisterns, heated by the flues of a furnace operating over their surface. When sufficiently concentrated, the liquor is run off into coolers, when the sulphate of iron, which is less soluble than the sulphate of alumina, crystallizes, leaving the latter in solution. The alum liquor is afterwards run off to be treated separately.

Sulphate of iron is much used in the arts. Added to an infusion of Aleppo galls (which contain *gallic acid*) a dark blue-black solution of *gallate of iron* is formed, which, with the addition of a little gum arabic and lump sugar, produces

the best black ink of commerce. With the addition of acetic acid and alcohol, a solution of sulphate of iron constitutes one of the most active *developing* agents used by photographers to develop, or render visible, the latent image impressed by light upon iodide of silver, in the camera. Sulphate of iron is also used in dyeing and calico-printing, and when calcined at a red heat it forms the jewellers' rouge employed for polishing gold and silver, glass, marble, &c. It is also used as a tonic in medicine.

*Perchloride of Iron.*—Peroxide or Sesquioxide of Iron, or red hematite, is very soluble in hydrochloric acid, forming a yellow-red solution of *perchloride of iron.* The ore being exceedingly abundant and cheap, it occurred to the author, a few years since, to adopt it as a medium for manufacturing prussian blue, jewellers' rouge, and a bright red pigment of great beauty. The processes were not a commercial success, owing to what is called the "conservatism" of the colour trade—which means a system of boycotting applied to all but existing and "recognized" manufacturers of pigments, and those "middle men" who, being in the same ring, rigidly block the way when a new manufacturer dares to venture into the field of competition.

The method adopted was as follows:—The native ore, after being reduced to powder, was placed in a series of stoneware pans, surrounded by a "jacket" of wood, and heated by steam. A quantity of commercial hydrochloric acid was first poured into each pan, and to this the powdered ore was added, a little at a time, with occasional stirring, and the steam then turned on. When the full charge of powdered ore was given, the pans were well stirred about every fifteen minutes, after which the wooden lids which covered each pan were placed over them. In about twenty-four hours the solution of perchloride of iron was drawn off and transferred to a large vat; to this

was then added a solution of ferrocyanide of potassium, which precipitated the iron in the form of *ferrocyanide of iron*, or prussian blue, which, after repeated washings, was strained and carefully dried. To obtain a bright red pigment, the perchloride was first diluted with water, and to this solution was added strong liquid ammonia, which formed a brown precipitate of *hydrated peroxide of iron*, which was now boiled until the brown precipitate assumed a bright orange-red colour, when it was carefully washed to remove the chloride of ammonium formed during the decomposition of the perchloride and ammonia. The precipitate was afterwards strained, dried, and heated to low redness, by which it acquired a beautiful bright red colour. By slightly augmenting the heat, a darker tone was obtained, and in this condition the product represented jewellers' rouge of the finest possible quality, and was greatly admired by the few who had the courage to use it. The "trade," however, with these exceptions, would not adopt it because their polishers (who received commissions from the rouge makers who supplied them) refused to recognize the new article. The ammonia used in the above process was recovered by first mixing lime with the chloride of ammonium, and afterwards obtaining the ammonia by distillation, which was used over and over again, rendering the process exceedingly economical.

*Scrap Iron* is used for throwing down metallic copper from its acid solutions, as the sulphate of copper, for instance, which impregnates the waters of the copper mines. Sulphuric acid, having a greater affinity for iron than copper, seizes the iron, forming sulphate of iron, whereby the copper is set free, and deposits upon the metallic iron in the form of pure copper, which is afterwards collected, dried, and melted in a furnace.

Iron enters largely into pharmaceutical preparations, forming medicinal compounds which are extensively used by the medical

profession. Among the more important of these we may mention :—

*Quevenne's Iron*, which is pure *metallic iron*, in a very finely-divided state. This is prepared by placing in a porcelain "gun-barrel" as much sesquioxide of iron as will occupy about ten inches of the middle of the barrel, which is kept in its place by plugs of asbestos. The middle part of the barrel is next exposed to a red heat in a suitable furnace, after which a stream of *hydrogen gas* is passed through the barrel until it is no longer absorbed, when the barrel is removed from the fire, and the current of hydrogen allowed to pass into it for a still further time. When cold, the metallic powder is withdrawn and put into a well-stoppered bottle. It is given, in doses of five to ten grains, as a mild but certain chalybeate, and is easily dissolved by the juices of the stomach.

*Citrate of Iron* is formed by digesting iron filings in a strong solution of citric acid (the acid of lemons), and evaporating the solution as quickly as possible out of contact with the air, when it forms a white powder, which is readily acted upon by the air. It is frequently mixed with quinine, and administered under the name of *citrate of quinine and iron*.

*Lactate of Iron* is formed by boiling iron filings in *lactic acid* (the acid of sour milk) diluted with water, until gas ceases to be evolved, when the solution, while still hot, is filtered into a suitable vessel, which must be at once closely stopped. As the solution cools, greenish crystals of lactate of iron deposit, which are afterwards washed with alcohol, and then dried.

*Tartrate of Iron.*—This is prepared by digesting iron filings in a hot solution of tartaric acid, when, after filtering the turbid solution, a brown powder is obtained, which is afterwards dried, bottled, and carefully stopped.

*Tincture of Sesquichloride of Iron. Steel drops.*—This well-

known tonic medicine is prepared by mixing alcohol with a strong solution of sesquichloride of iron in certain proportions, and precipitating the excess of iron with potash.

*Acetates of Iron* are formed by, 1. dissolving metallic iron in strong acetic acid, and concentrating the solution by evaporation, when very pale greenish crystals of *protacetate of iron* are obtained; or, 2, by adding a solution of *acetate of lime* to a solution of *persulphate of iron*, when *sesquiacetate of iron* is formed.

Besides the above, there are many other preparations of Iron, as the precipitated Carbonate of Iron, for example, used in medicine, all more or less efficacious as chalybeate remedies.

In Dr. Callan's well-known Maynooth battery—a voltaic battery which created a great deal of interest when first made known some five-and-thirty years ago—Iron is employed as the *negative* element. The battery consists of a cylindrical iron vessel, in which is placed the usual porous cell, and in which is a bar or plate of zinc. The iron vessel, which constitutes the outer cell of this battery, is filled with strong nitric acid, and a solution of sulphuric acid is poured into the porous cell. A binding screw connected to the zinc, and another attached to the iron cell, completes the arrangement. The battery is an exceedingly powerful one, but is rather expensive to work owing to the cost of the nitric acid.

Iron is used as a coating, or *facing*, for engraved copper-plates and electrotypes, to protect the softer metal from being worn by the process of printing. The process, which is called *acierage* by the French, consists in depositing iron from a solution of the double chloride of iron and ammonia, or other suitable solution of iron, by means of the voltaic battery or dynamo-electric machine. The pure iron—mistakenly called steel—facing thus given to engraved plates or electrotypes

enables the printer to produce an unlimited number of copies of equal beauty. After a certain number of copies have been taken from the plate, the iron is dissolved off by dilute acid, and a fresh coating deposited by the battery as before. The original copper-plate, or electrotype, is thus protected from the wear and tear of machine printing, and will last unimpaired for an indefinite period. Previous to the application of the art of electro-deposition in the steel, or rather iron-facing of engraved copper-plates, only a limited number of good impressions were obtainable, hence the high price charged for "proofs" and early copies. Nickel has also been applied to this purpose, and with much advantage, owing to its extreme hardness, but the ease with which the iron can be removed from the plate, and a new coating given, renders the iron-facing more practicable.

A mixture of iron filings, acetic acid, and nitro-benzol, subjected to distillation, yields the substance called *aniline*, from which the beautiful dyes, known as *aniline dyes*, are obtained by treatment with bichromate of potash and certain other oxidizing agents.

In dyeing, the black is usually produced by logwood or galls, with a mordant of *acetate of iron;* for silks, a bath of nut-galls is first given, and after rinsing and drying, the pieces are passed for a few minutes through a bath containing *sulphate of iron;* for wool, the goods are first dyed a deep blue, either with indigo or prussian blue. They are afterwards dyed black in a bath composed of a decoction of logwood chips and Aleppo galls, to which copperas, or sulphate of iron, is added.

## CHAPTER X.

### Manufacture of Steel—Bar Steel, or Steel of Cementation—Shear Steel—Cast Steel, or Crucible Steel—Bessemer's Process for making Steel.

Amongst the many remarkable discoveries, inventions and improvements which have so repeatedly taken the public by surprise during the past forty years or so, may properly be mentioned the important improvements in the manufacture of that indispensable compound of Carbon and Iron known as *Carburet of Iron,* or more commonly, Steel. The vast number of purposes to which Steel is applied—and for which, indeed, we have no substitute—renders its economical manufacture and abundant supply, a matter of the greatest concern to all civilized communities. So great has been the increase in its production, more especially during the past five and twenty years, that Steel is fast becoming a substitute for Iron for many purposes, including the rails or "metals" of our railways. Steel is also largely used in the manufacture of powerful ordnance, including shot and shell, and will probably supersede Iron in the construction of all maritime vessels. The presence of traces of Carbon in some Wrought Irons, which should be quite free from it, causes them to approach steel in character, which is not always a desirable qualification in wrought iron. Even the softest and purest Iron generally contains about 0·2 per cent. of carbon.

A product called *Natural Steel* is much used on the continent for making agricultural implements. This is generally made from white cast-iron, which contains but little carbon, does not flow thin, and which being "cemented" over or above the

wind, falls down at once through the blast to the bottom of the hearth in the condition of Steel. If the metal runs too fluid, lumps of malleable iron are introduced to give the molten mass a thicker consistence. If the natural steel contains too little carbon, the metal bath, covered with its cinder slag, is stirred with a *wooden* pole, or additions of a more highly carburetted iron are given. When it contains the right proportion of carbon and acquires the requisite stiffness, it is removed from the furnace, subjected to the forge hammer, and then drawn into bars.

*Bar Steel, Steel of Cementation, or Blistered Steel.*—Prior to the introduction of the processes shortly to be referred to, the Steel manufacture of this country was chiefly confined to the use of Swedish and Russian Irons, the former, stamped with the letter L, enclosed in a circle, and hence called "hoop L," or "hoop Iron," having the preference over all others.

The process of *cementation,* as it is termed, consists in imbedding bars of iron in ground charcoal, and sometimes soot, mixed with one-tenth of ashes and a little common salt. The operation is conducted in a furnace, divided by a grate into two parts, on each side of which is a chest called a "trough," made from fireclay. The bottom of the trough is first covered with the above mixture, and the bars are then laid upon this, but are not allowed to touch. A layer of the powder of cementation is then spread over the bars, to the depth of about an inch, upon which a fresh layer of bars is placed, and so on until the furnace is filled to within a few inches of the top, the remaining space being filled up with old cement powder. The fire is then gradually urged for three or four days till it acquires a suitable temperature, which is kept up for a period of four to ten days, according to the size of the furnace. Test pieces are examined from time to time, as also the bars, until the cementation is found to be complete. The trial bars are cut longer than the

others, so that their ends may project, and those ends are enveloped in fireclay. For steel of moderate hardness, from six to eight days' cementation is sufficient; for a harder steel, as for chisels used in cutting iron ("cold chisels"), a longer period is necessary; and for a much softer steel, such as would be used for springs, saws, &c., a much shorter period is required. The steel used for making bits for boring cast-iron requires to undergo the above process several times.

When the operation is complete, the furnace is allowed to cool, and the steel bars are then withdrawn by a workman who enters the furnace for that purpose. The bars are covered with blisters, caused by the formation and bursting of vesicles filled with gaseous carbon, hence the name *Blistered Steel* has been given to this kind of steel. In its present condition, however, it is full of cavities and irregularities, and requires to be forged by the steam-hammer. In some works, as at Sheffield, *tilt-hammers* are used thus: "At a small distance from each tilt-stands the forge-hearth, for heating the steel. The bellows for blowing the fire are above-head, and are worked by a small crank fixed on the end of the axis of the wheel, the air being conveyed by a copper pipe down to the nozzle. Each workman at the tilt has two boys in attendance, to serve him with hot rods, and to take them away after they are hammered. In small rods, the bright ignition originally given at the forge soon declines to darkness; but the rapid impulsions of the tilt revive the redness again in all the points near the hammer, so that the rod, skilfully handled by the workman, progressively ignites where it advances to the strokes. Personal inspection alone can communicate an adequate idea of the precision and celerity with which a rude steel rod is stretched and fashioned into an even, smooth, and sharp-edged prism, under the operation of the tilt-hammer. The heat may be clearly referred to the pro-

digious friction among the particles of so cohesive a metal, when they are made to slide so rapidly over each other, in every direction, during the elongation and squaring of the rod."—*Ure.*

*Shear Steel.*—This kind of Steel received its name from the fact that the shears used for dressing woollen cloth were generally made from it. The process for making this steel consists in binding several bars of blistered steel, each about 18 in. long, with a slender steel rod, into a bundle, the projecting end of the latter forming a handle. This, called a *faggot,* is then heated in the forge-hearth to a good *welding heat,* and sprinkled over with sand to form a protecting film of iron slag; it is then carried to the tilt and notched down on both sides to unite all the bars together and close up every flaw. The mass is again heated, the binding rings knocked off, and it is then drawn out into a uniform rod of the required size. By this treatment the metal is rendered so compact by the welding and hammering which it receives that it will take an exceedingly fine polish, and is greatly improved in tenacity and malleability, and is specially adapted for making table knives, scissors, powerful springs, &c. The terms *shear, single shear,* and *half-shear* express the amount of doubling and welding which the bars have received.

*Cast Steel or Crucible Steel.*—This is a very fine quality of steel, and is much used for many important purposes. Bars of blistered steel are first broken up into small fragments, after which they are melted in *crucibles,* and then poured, while in a fluid state, into cast-iron ingot moulds. The heat required for the fusion of the metal is very great, so that the crucibles, or melting-pots, require to be made from refractory clay of the best quality. The crucible, being placed on a sole-piece of baked fireclay, is covered closely with its lid. Sometimes a little bottle-glass, or blast-furnace slag is put into the crucible, above the fragments of steel, to form a vitreous coating to prevent the

oxidation of the metal. The fuel employed for fusing the metal is dense coke broken into small pieces. When the fusion is complete, the lid is removed, the slag cleared away, and the metal is then poured into cast-iron moulds, at which time it throws out most brilliant scintillations.

The art of melting steel in crucibles, forming *Crucible-Steel,* as it is termed, is due to a Quaker named Huntsman, of Sheffield, who carried on the manufacture as a secret process for a number of years, and his steel attained a high celebrity. It is said that the secret of its manufacture was gained by stealth, the story of which is briefly given at page 99. Dr. Percy thus describes the construction of a mould from which crucibles are made for steel casting:* "It consists of a circular cast-iron case, or 'pot mould,' open at the top and bottom, and turned in the interior of the same dimensions as the exterior of the pot. It has two projecting pieces, one on each side, by which it may be conveniently lifted (fig. 15). In this case fits a plug of hard wood, such as lignum vitæ, turned of the same dimensions as the interior of the pot; on the top is a head of iron to receive the blows of a mallet, and in this head is a transverse hole through which an iron pin may be passed to serve as a handle, and for turning the plug round; from the bottom of the plug an iron spindle protrudes. In the pot mould is a loose disc of iron, just large enough not to drop out at the lower or small end, and having a hole in the centre for the passage of the spindle. The pot

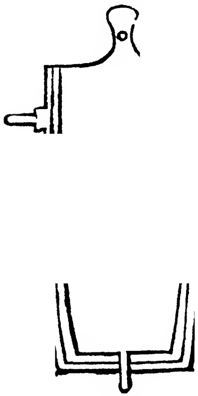

Fig. 15.

* "Metallurgy; Iron and Steel." By John Percy, M.D. F.R.S.

mould being well smeared with whale oil, is placed upon a low post solidly fixed in the ground, and having a hole in the middle to allow the spindle of the plug to descend. The charge of clay, in the form of a short cylinder, is put into the pot mould, and the plug, also well oiled, is then driven two or three inches down by means of a heavy mallet, the spindle at the top keeping it in the centre. The plug is then withdrawn, with a screwing motion, by means of the movable pin on the head, as above described, after which it is oiled afresh, again inserted, and driven home, the clay rising in the space between the plug and the interior of the pot mould. The clay is cut level with the top of the mould with a knife, and the plug is taken out of the pot. The top is narrowed somewhat by inserting a knife between it and the corresponding part of the pot mould, and holding it inclined towards the centre. The pot mould is then set upon a short post, so that its loose bottom may be gently forced up with the pot upon it. The pot is then removed to a warm place to dry. The lids are made of the same material as the pot."

Before being placed in the casting-furnaces, the pots, after thoroughly drying, are *annealed,* as it is called, that is, they are *gradually* heated to redness; for this purpose a number of the pots are placed, mouth downwards, with their lids resting on the bottom of the pots, on the "grate," containing hot coal, after which coke is filled in between them. If this be done overnight, the pots are ready for use on the following morning, when they are placed upright, their lids being put properly on, in the furnaces, which have been already supplied with live coal from the fireplace. The method of melting the blistered steel is thus described by Dr. Percy: "One or two pots, as the case may be, previously 'annealed,' are placed in each furnace, and a handful of sand is thrown into each pot, to stop up the hole

left by the spindle of the plug used in moulding. The pots are then 'brought up,' *i.e.*, raised to a high temperature, and in about twenty minutes a charge of broken up and assorted blister-steel of from 30 lb. to 40 lb. in weight is introduced through a funnel-shaped charger of sheet iron, and the mouth of the pot is then closed with a clay lid, and the furnace filled up with coke. After the lapse of three-quarters of an hour the furnace is again replenished with fuel. In another three-quarters of an hour the fireman takes off the lid of the pot to examine the progress of the melting, and, according to his judgment, more or less coke is added to complete the process. As soon as the steel is perfectly molten, and ready for 'teaming,' the 'puller out,' having enveloped his legs in sacking, and freely besprinkled them with water, stands over the furnace-hole, or mouth, whilst the 'cellar lad' loosens the pot from clinker adhering to the bottom of the furnace. With one good hoist, the pot is transferred to the 'teaming hob,' a rectangular box about 18 in. square, and of the same depth, let into the floor of the casting-shop, and having a quantity of coke dust on the bottom, so that the pot may be prevented coming in contact with the iron, and cracking in consequence. The lid is removed, and placed upon the pot which has just been teamed, which is then immediately returned to the furnace. The chief melter then takes hold of the pot with the 'teaming tongs,' and pours out the steel, taking care to avoid touching the sides of the mould."

*Bessemer's Process for Making Steel.*—If we except the splendid discoveries of Mr. Perkin—resulting in the production of those marvellous aniline colours from coal-tar, which so completely revolutionized the dye-stuff trade both at home and abroad—there is no manufacture which has undergone so sudden and eventually so complete a change as that of Steel. When, in the year 1855, Mr. (now Sir Henry) Bessemer made

known his first process for making Steel upon a new system, the interest attached to it was immense; and although, as it subsequently turned out, the process was not so perfect as had been at first anticipated, those most interested in the subject had great hope that the then existing difficulties would be overcome, as was indeed the case eventually, by the gifted inventor himself, who in subsequent patents supplied the missing links which rendered the process complete.

The following extracts from an admirably-written article on "Steel"* will be read with much interest:—

"No metallurgical discovery has been more pregnant with benefit to the world in general, or more profitable to its author, than the invention universally known as the *Bessemer Process.* Although it is little more than twenty-two years [written in 1877] since Bessemer first made known his tiny experiment with about 25 lb. of metal in a small crucible, and less than twenty years since he explained to the Institute of Civil Engineers his complete plans for working the process on a commercial scale, so rapid has been the growth of the manufacture, that it is estimated that in the year 1877 over *two million tons* of steel were actually made by the Bessemer process. Estimating this at only £5 per ton in the ingot, we have the enormous sum of £10,000,000 sterling as the value of the raw Steel produced by this process in one year—the actual value of the finished articles being about double this amount. Or, to put the matter in another light, there are at the present time close on three hundred and fifty Bessemer converters in existence. . . . Bessemer's first experiments were made on a small scale at his bronze manufactory in London, where, in order to test his ideas regarding the refining of iron

* In "Chemistry as Applied to the Arts," &c.

by blowing air *through* it, he had a small crucible furnace constructed, and after melting about 25 lb. of pig-iron in a crucible, he passed a clay pipe through the metal, and forced a current of air through it for some time. The result was that he blew out and wasted about half the material; but the remaining half proved to him conclusively that if air was blown upward through the molten iron, instead of merely *on to its surface*, as in the old Welsh refinery, much greater refining action was produced. His aim was to produce, if possible, an improved metal for guns. Having satisfied himself thus far, he took out his first patent, dated October 17, 1855, for 'Improvements in the manufacture of Cast-steel.'"

In this process Bessemer proposed to use crucibles in a rectangular furnace, the firebars of which were to be at the side instead of at the bottom, through which the metal was to be tapped into a mould beneath at the proper time. Steam, air, or both, were to be forced through a pipe to the bottom of the pig-iron, which was to run into the hot crucible in a fluid state. The invention was described as consisting in "forcing currents of air or steam, or of air and steam, into and among the particles of molten crude iron, or of melted pig or refined iron, until the metal so treated is hereby rendered malleable, and has acquired other properties common to cast-steel, and still retaining the fluid state of such metal, and pouring or running the same into suitable moulds." The inventor states that "steam cools the metal, but air causes a rapid increase of temperature, causing it to pass from red to an intense white heat."

In December of the same year, Bessemer obtained another patent for blowing the air through the molten iron, which was to be contained in a spherical or egg-shaped vessel of iron, lined with firebrick and suspended upon axes; and when the process had been carried far enough, the metal was to be

poured from the vessel into moulds. "This arrangement," says the writer referred to, "is clearly the first germ of the idea of tipping the vessel on axes to discharge the fluid iron, instead of tapping it through a hole in the bottom of the crucible; but in this apparatus the single blowpipe carrying the air downwards to its escape orifice was still retained. Later on, however (May, 1856), we find Bessemer patenting an upright fixed cylindrical vessel, with several twyer pipes permanently fixed into, and forming part of, the lower lining of the vessel. This form of converting vessel has been extensively adopted in Sweden for working small charges of metal." Bessemer subsequently designed another vessel, which is now generally known as the "Bessemer converter," in which considerable improvements were introduced, whereby it was applicable to manufacture on a more extended scale. In 1862, he obtained a patent for the employment of a pair of converting vessels, with a centre casting vessel between them—"the whole being moved by hydraulic power, and forming such an efficient set of apparatus for carrying out the process, that although very many clever men have since done their best to improve upon these plans, the essential portions are retained in the most approved plants of the present day."

There is a method of making *natural steel*, much practised in Germany, where the best cast-iron is produced from spathose iron ores. The spathose iron ores being free from those impurities which are present in the ores chiefly used in England, produce a very superior cast-iron, and consequently its conversion into steel is a comparatively simple process. The iron to be converted into steel is cast into plates; a charcoal fire is kindled in the hearth of the furnace, and the plates are melted before the blast. When the metal fuses, a quantity of iron scale (oxide of iron) and rich scoria is added, to assist in the oxidation of the carbon of the iron.

## CHAPTER XI.

**Manufacture of Steel continued—Siemens' Process for Making Steel — Mushet's Steel Process — Hindoo Process — Damascus Blades — Damaskeening — Case-hardening— Hardening and Tempering Steel.**

AMONG the many important improvements in the manufacture of Steel must be included those of Dr. C. W. Siemens and his colleague M. Martin, of Sileuil, near Paris; but before giving a slight sketch of the Siemens-Martin process—by which name it is now generally known—it may be well to state that as far back as 1845, Mr. Heath obtained of patent for a process of making Steel by melting "scrap-iron," or other malleable iron, in a "bath" of pig-iron, in a reverberatory-furnace heated by gas. The process was not successful, however, owing to the difficulty he experienced in producing a sufficiently high and uniform heat. Other patented processes followed Heath's, as a matter of course, but it was not until Dr. Siemens perfected his regenerative gas-furnace that the manufacture of steel by a gas-furnace was really successful. The first practical use of this furnace for steel-making in England was made by Attwood, while in France M. Martin was even more successful. In the year 1867, Dr. Siemens turned his attention to this subject, and erected an experimental furnace at Birmingham. Soon after this he obtained a patent for a process which was at once found to be successful, and the Landore Siemens' Steel Company was established, and four five-ton furnaces were erected for carrying on the manufacture on a large scale. The importance of the Siemens' regenerative furnace for making

steel on what is termed the "open hearth system," has led to the terms "Siemens," or "Siemens-Martin," Steel to all steel made by the open hearth process.

In the Siemens' furnace, the "regenerators" are placed below the bed of the furnace, one being employed for heating air and the other for gas. The bed is made of finely-ground quartz sand, consolidated by pressure and heat, and rests upon cast-iron plates, which are kept cool by the circulation of air. The surface of the bed is flat, but slightly inclined towards the top hole situated below the working-door. The "ladle," which has a hole in the bottom, as in Bessemer's process, is mounted on wheels, and travels upon a railway—the ingot moulds being arranged in a pit below.

The *charge*, depending on the size of the furnace, ranges from 35 cwt. to 5 tons, and the materials are good pig-iron, such as is used in the Bessemer process, wrought-iron bars, malleable scrap-iron, or Bessemer steel cross-ends and waste *spiegeleisen*.* Dr. Siemens thus described his process for producing cast-steel, in a lecture before the Chemical Society:— "The process chiefly employed at the Landore Works consists of introducing on the bed of an intensely-heated regenerative gas-furnace about six tons of pig metal, which may be No. 3 or 4 hematite pig. When a fluid bath has been formed, oxide of iron, which should by preference have been smelted beforehand, with such proportions of lime, or other fluxing material, as to form with the silica in the ore, and in the pig metal, a convenient slag, is added; or natural ores may be used in their raw condition if they contain lime and manganese, as for

* Spathose, or sparry iron ore, found chiefly in Germany. It is much valued for producing iron crystallizing in large plates. It is a protocarbonate of iron.

example, the African Mokta ore. When about 30 cwt. of this ore has been dissolved (with ebullition) in the metallic bath, it is found that a sample taken from it contains only about 1 per cent. of carbon, a point easily detected by the eye of the workman by a peculiar bright appearance of the sample when chilled in water and broken by a hammer. Considerable difficulty was experienced to find a material to resist the excessive heats necessary for carrying out this process: ordinary Dinas bricks, which are considered the most refractory material in general use, would be rapidly melted, but a brick specially prepared by crushing pure quartz rock, and mixing it with no more than 2 per cent. of quicklime, to give cohesion, answers well. The hearth of the furnace is made of white sand, with a small admixture of more fusible fine sand, which mixture sets exceedingly hard at a steel-melting heat, and possesses the advantage of combining into a solid mass with fresh materials introduced between the charges to make up for the wear and tear. The hearth and furnace roof, if of the materials just specified, are very little attacked when the Siemens-Martin process is used, although the heat must be sufficient to maintain wrought-iron, containing only a trace of carbon, in a perfectly fluid condition."

In conducting the process, the pig-iron is first melted, and to this malleable iron, or steel, previously brought to a white heat by exposure to the stream of gas on the bridges, is added a little at a time. The reversal of the gas and air valves takes place every twenty minutes. When the full charge is dissolved, a sample is taken out in a small wrought-iron ladle, and cast, and this is afterwards chilled in water, broken, and examined. The heat is continued with an ordinary flame, until the sample, although suddenly cooled, yields a perfectly soft and tough metal, thereby indicating that the *decarburization* (or removal of

the carbon) is complete.* The spiegeleisen is now added, which becomes melted in about twenty minutes, when the charge is quickly stirred, to ensure perfect uniformity of the mixture. The contents of the furnace are next run into the ladle and cast into ingots. Three charges are generally made in every twenty-four hours, the yield being, for a 35 cwt. charge, from 32 to 33 cwt. By the above treatment of the pig-iron all the carbon, silicon, and manganese which it may contain are completely burnt out, whereby it is converted into almost absolutely pure iron, provided the ore from which the pig-iron was made was free from sulphur and phosphorus.

Heath discovered the advantage of manganese in making steel; and Mushet† originated the idea of applying it in the form of a metallic alloy. Thus we see at the present day, both in Bessemer's and in Siemens' processes — developed under more favourable conditions than were practical in the days of those indefatigable workers‡—that the full development of a great art is not the work of one generation or of one mind; and how many gifted men have given, and still are devoting, their thoughts to accomplish seeming impossibilities! By the introduction of molten spiegeleisen to decarburetted iron, and thereby restoring a *fixed* quantity of carbon, and adding manganese to the product, Bessemer rendered his process perfect; so also, under different conditions, did Siemens perfect his method of making steel.

* At this point the flame suddenly drops, and the workman can tell, even by the change in the *sound*, that the carbon is burnt out.

† It was Mushet who also discovered the since well-known "blackband" ironstone, about the year 1800, which gave an immense impetus to the Iron manufacture of Scotland.

‡ The uses of gas, even for illuminating purposes, were not made known by William Murdock until some years after Mushet's patent.

In making malleable steel, when a very soft metal is required, ferro-manganese is added to the decarburetted iron; for rail or tool steel spiegeleisen is introduced, and for steel castings a mixture of ferro-manganese and silicious pig-iron, or an alloy of silicon and manganese. With six-ton charges, from seventy to a hundred tons of steel ingots can be produced from one furnace.

In Siemens' "ore process," as it is called, hematite and iron ore, free from phosphorus and sulphur, are added to the charge of pig-iron; during the operation of the heat, the metal is kept in a boiling state, when all the carbon, silicon and manganese become removed by the reaction which takes place between the oxygen of the ore (oxide of iron) and those constituents of pig-iron. Samples are taken from time to time, until the metal is found to be perfectly malleable under the hammer. The spielgeleisen is then added, and the metal quickly run out to prevent loss of their substance. From 20 to 25 cwt. of the ore are required for a five-ton charge, and, according to Hackney, "of the metal contained in the ore, about one-half passes into the steel, so that, as the carbon and silicon in the pig amount to about 8 per cent., the yields of ingot and scrap is generally 1 to 2 per cent. more than the weight of pig-iron and spiegeleisen put in."

In working Siemens' "scrap" and "ore" processes, when the supply of scrap is limited, this is divided amongst the furnaces, and the charges made up by adding ore.

*Mushet's Steel Process.*—There are so many interesting features in this process—especially at the present day, when the progress of science has enabled us to finish so much of what our forefathers had begun—that we are tempted (regardless of chronological order) to give a slight sketch of the process here. A patent was granted to David Mushet in 1800, for a process of manufacturing cast-steel, &c., which consisted in fusing malle-

able iron (either bar or scrap-iron), or iron ore when sufficiently rich and pure, in crucibles, with a certain percentage of carbonaceous matter. By this process, different qualities of steel were produced according to the proportion of carbon introduced, the smaller proportions giving a softer metal, as required. The following is an extract from his specification: "Steel produced with any proportion of charcoal [carbon] not exceeding $\frac{1}{100}$, will generally be found to possess every property necessary to its being cast into those shapes which require the greatest elasticity, strength and solidity; it will also be found generally capable of sustaining a white heat, and of being welded like malleable iron; and indeed, as the proportion of the charcoal, or other carbonaceous matter, is reduced, the qualities of the steel will be found to approach nearer to those of common malleable iron." In his "Papers on Iron and Steel," Mushet thus describes the attributes of the metal produced by his method: "When the iron is presented in fusion to $\frac{1}{140}$ or $\frac{1}{150}$ of its weight of charcoal, the resulting product occupies a kind of middle state between malleable iron and steel. It then welds with facility, and, with proper precautions, may be joined to iron or steel at a very high welding heat. Thus combined with carbon, it is still susceptible of hardening a little, but without any great alteration in the fracture. It possesses an enormous degree of strength and tenacity, and is capable of an exquisite degree of polish, arising from its complete solidity, and the purity of fracture conveyed to it by fusion. When the dose of carbon is further diminished, and in the ratio of this diminution, the same steel or iron becomes more and more red-short, and less capable of cohesion under a welding heat; so that when the proportion is reduced to $\frac{1}{200}$ part of the weight of the iron, the quality resulting is nearly analogous to the fusion of iron *per se*, or that obtained by the fusion of iron and earth."

*Hindoo Process for Making Steel.*—This method, from its simplicity, and the excellence of the steel produced by it, will be read with interest after perusing the more elaborate and scientific processes just given. The process is thus described by Dr. Buchanan, a very high authority upon Indian arts and manufactures: A wedge of iron, forming about a third part of one of the little lumps produced in an ordinary Hindoo iron furnace, is put into a conical unbaked clay crucible, of about the capacity of a pint, with the addition of three rupees weight (531 grains) of the stem of *Cassia auriculata*, and two large smooth green leaves of a species of Convolvulus or Ipomœa. The crucible, thus charged, is closed at the mouth with a cap of unbaked clay, well luted on, and then well dried near a fire. The furnace used is a little circular pit in the ground, somewhat dilated at the top. An earthen pipe, connected with two bellows, each consisting of bullocks' hide, and which are worked alternately, enters the fire-place at the bottom. A row of crucibles is first laid round the sloping mouth of the fireplace, then within these another row is placed, and the centre of the arch thus formed is occupied by a single crucible, making in all fifteen. The crucible in the outer row, opposite the nozzle of the bellows, is then taken out and in its stead an empty crucible is placed horizontally, with its mouth directing inwards. This crucible can be readily drawn out and replaced, and the opening which it closes constitutes the firehole through which the fuel is introduced. The fuel is charcoal, with which the fireplace is filled, and the arch of crucibles, charged as stated above, is covered over. The bellows are then plied during four hours, when the operation is completed. A new arch of crucibles is constructed, and the process goes on night and day; five sets of fourteen crucibles each being every day worked off. On breaking open the crucibles, the steel is found melted into the well-known conical cakes of *wootz*, which

usually present a radiated wrinkling on their upper or flat surface. The cakes weigh a little over 2½ lb. each.

Cast-steel, being exceedingly hard, is much used in making cutting instruments and edged tools; and since iron and steel, when heated together, became readily united, certain tools made of iron are faced, or pointed with steel, whereby effective implements are obtained economically. Pick-axes, choppers, spades, garden-hoes, plane-irons and many other implements are manufactured in this way. When a piece of iron is placed in the mould in which steel is cast, the two metals adhere, and may be rolled together as one substance. The extreme toughness of iron renders it specially suited for all parts of the implement but the cutting edge, to which the steel facing gives the necessary hardness.

There are numerous other processes for making steel, including the Continental systems, which the reader will find fully described in the various admirable treatises and technical works mentioned in these pages, and to which the reader is referred for more detailed information upon this interesting subject.

Steel is considered a true chemical compound of Iron and Carbon, although the latter substance only exists in steel in infinitesimal proportions. Indeed less than one-half per cent. of carbon, *chemically combined* with iron, produces those remarkable properties which distinguish Steel from Iron, and render it serviceable to purposes for which iron would be useless. For example, Steel is so much harder than iron that it will cut or file that metal; it will scratch and even cut the hardest glass; it will produce sparks if struck against a piece of flint; it is susceptible of a higher polish than iron; it is more elastic, and when converted into a spring will return to its original position after being expanded; it will take and retain after considerable

use a delicately fine edge; it does not oxidize or rust so readily as iron; its polished surface acquires the most beautiful prismatic colours, or may be rendered uniformly blue, or yellow, by a moderate heat; when made red-hot, and then suddenly cooled, it becomes harder, more brittle and less pliable than Iron, but when again moderately heated or *tempered,* it recovers its elasticity, while retaining to a great extent its hardness; and finally steel is capable of acquiring and retaining the remarkable property known as *Magnetism.*

The celebrated *Damascus blades,* so highly prized for the beauty of their variegated surface, or *watering,* as it is called, are made in Damascus, in Syria, from whence their name is derived. The extreme ingenuity of the Eastern workmen is shown not only in the great variety of effects produced, but in the processes by which they are obtained. The sword and scimitar blades of Damascus often present white, silvery, or black veins, in fine lines or fillets, fibrous, crossed, interlaced or parallel. After many attempts to discover the methods adopted by the Syrians, M. Bréant at last solved the problem. Dr. Ure remarks, "He has demonstrated that the substance of the Oriental blades is a cast-steel more highly charged with carbon than our own European steels, and in which, by means of cooling suitably conducted, a crystallization takes place of two distinct combinations of carbon and iron. This separation is the general condition; for if the melted steel be suddenly cooled in a crucible or ingot, there is no damascene appearance. If an excess of carbon be mixed with iron, the whole of the metal will be converted into steel, and the residuary carbon will combine in a new proportion with a portion of the steel so formed. There will be too distinct compounds, namely, pure steel, and carburetted steel, or cast-iron. These at first being imperfectly mixed, will tend to separate, if while still

fluid they be left in a state of repose, and form a crystallization in which the particles of the two compounds will place themselves in the crucible in an order determined by their affinity and density conjoined. If a blade forged out of steel so prepared be immersed in acidulous water, it will display a very distinct damascus appearance, the portions of pure steel becoming black, and those of carburetted steel remaining white, because the acids with difficulty disengage its carbon. The slower such a compound is cooled, the larger the damascus veins will be. Travernier relates that the steel crucible ingots, like those of wootz [Indian steel] for making the true Oriental damascus, come from Golconda, that they are the size of a halfpenny roll, and when cut in two, form two swords."

*Damaskeening* is a term applied to ornamenting iron, steel, &c. by cutting designs upon its surface, and filling them up with gold or silver wire. The process is chiefly applied to the ornamentation of sword-blades and guards. This system of embellishment is partly mosaic work, relieved by engraving and carving. In the mosaic work, pieces of metal are inlaid; in the engraved work, the metal is indented or cut in intaglio; and when carved, gold and silver are driven into the hollowed surfaces. When the work is engraved, the artist cuts into the metal with the graver and other suitable tools, and afterwards fills up the incisions with gold or silver wire. The engraving is done after the dovetail fashion, so that the inlaid gold or silver may retain its position firmly. Sword blades and other steel articles are sometimes ornamented by the *etching* process.

*Case-hardening* is a term applied to iron subjected to a process by which a layer or coating of steel is formed on the *outer surface* while the interior of the object remains unchanged. Keys, iron tools and other articles of iron frequently have a superficial surface

of steel given to them by this process. The articles, when nearly finished, are placed in an iron box, embedded in powdered charcoal, and this is heated in a furnace for a short time, by which a thin coating of carburet of iron, or steel, is imparted to them. Another method is to rub, or sprinkle over the polished article, while red-hot, a little powdered prussiate of potash (*ferrocyanide of potassium*) which soon becomes decomposed. The article is then plunged into cold water, when the surface becomes so hard as to resist the action of a file.

*Hardening and Tempering Steel.*—When steel, after being heated to redness, is plunged into cold water, it becomes exceedingly hard and brittle, and if again made red-hot and allowed to cool gradually, its original softness and malleability are restored. If now it be heated *below* redness, and then plunged into cold water, it will not become hardened, but will probably—according to the temperature at which it was heated—acquire a degree of hardness midway, so to speak, between the extreme limits of hardness and softness. The process of imparting various degrees of hardness to steel by first heating, and then cooling it under certain conditions of temperature, is called *Tempering*. In the process of tempering, the steel is first rendered as hard as it can become by being made red hot and afterwards cooled suddenly, and it is subsequently reheated and suddenly chilled at different temperatures, according to the "temper," or degree of hardness required in the steel article, and which is regulated by the purpose to which it is to be applied. "During the process of reheating," says Dr. Percy, "the surface of the steel, having being previously brightened, will present a succession of characteristic colours corresponding to the different temperatures, and consequently these colours render the use of thermometrical instruments unnecessary."

The following Table gives the colours referred to in the order of their appearance at certain temperatures :—

| Degrees of Temperature. Centigrade. | Degrees of Temperature. Fahrenheit. | Colour. | Temper of Various Articles. |
|---|---|---|---|
| 221 | 430 | Very pale yellowish. | Lancets. |
| 230 | 450 | Pale straw. | Best razors and most surgical instruments. |
| 243 | 470 | Full yellow. | Common razors, penknives, &c. |
| 254 | 490 | Brown. | Small shears, scissors, cold chisels for cutting iron *cold*, hoes, &c. |
| 265 | 510 | Brown dappled with purple spots. | Axes, plane-irons, pocket knives. |
| 277 | 530 | Purple. | Table knives, large shears. |
| 288 | 550 | Bright blue. | Swords, watch-springs, bell-springs. |
| 293 | 560 | Full blue. | Fine saws, daggers, augers. |
| 316 | 600 | Dark blue. | Hand and pit saws. |

After having made a series of experiments on the hardening of steel in different liquids, such as mercury, water charged with different salts and acids, Caron concludes that the hardness and other effects produced by the process appear always to be inversely proportionate to the square of the time of the cooling of the metal, which again depends upon the temperature, the specific gravity, the specific heat, the conductivity, and "perhaps also on the mobility of the liquid employed in hardening."

In the tempering of steel, many different plans have from time to time been adopted to suit the nature of the article to be treated. Thus it must be obvious that needles, pens, springs, shears, axes and other large and small objects, require different treatment. Heated cast-iron plates, hot sand, heated oil, water,

acidulated water, tallow baths, molten metals and other means have been adopted for this purpose.

The following Table, published by Parkes many years ago, for the convenience of working cutlers, shows the melting points of alloys of lead and tin, and the temperature of boiling linseed oil for tempering the various articles named :—

| No. | Articles to be Tempered. | Composition of the Bath. Lead. | Tin. | Temperature. F. |
|---|---|---|---|---|
| 1 | Lancets . . . . . . . | 7 | 4 | 420° |
| 2 | Other surgical instruments . . | 7½ | 4 | 430° |
| 3 | Razors, &c. . . . . . . | 8 | 4 | 442° |
| 4 | Penknives and some implements of surgery . . . . . . | 8½ | 4 | 450° |
| 5 | Larger penknives, scalpels, &c. . | 10 | 4 | 470° |
| 6 | Scissors, shears, garden hoes, cold chisels, &c. . . . . . . | 14 | 4 | 490° |
| 7 | Axes, firmer chisels, plane irons, pocketknives, &c. . . . . | 19 | 4 | 509° |
| 8 | Tableknives, large shears, &c. . | 30 | 4 | 530° |
| 9 | Swords, watch-springs, &c. . . | 48 | 4 | 550° |
| 10 | Large springs, daggers, augers, small fine saws, &c. . . . . | 50 | 2 | 558° |
| 11 | Pit saws, and some particular springs . . . . . . . | Boiling oil. | linseed | 600° |
| 12 | Articles which require to be somewhat still softer . . . . | Melted | lead. | 612° |

A very important process for tempering steel wire for pianofortes was patented by Horsfall, of Birmingham, in 1854, and which has proved highly successful. The subjoined extract from his specification, somewhat abridged, will explain the nature of the invention. After the wire has been drawn, by the usual process, to nearly the diameter which it is intended the finished wire shall have, it is subjected to the following treatment : The wire is heated to redness, and afterwards immersed in water or oil, by which it becomes hard. It is next plunged into a bath

of molten lead, or other bath having about the melting point of lead. The wire is allowed to remain in this bath until it has acquired the proper temper, the length of time depending upon the size of the wire. After this hardening and tempering process, the wire is subjected to a *final drawing*, by which it is reduced to its proper size. By this method the wire acquires the hardness and tenacity which admirably suit it for piano-fortes, &c.

## CHAPTER XII.

**Native Magnet, or Loadstone—Artificial Magnets produced by the Native Magnet — Magnetization by Artificial Magnets—Magnetization by the Electric Current.**

The remarkable Iron ore commonly called *Loadstone* or *Lode-stone*, and also known as *Magnetite, Magnesian Stone, Magnetic Oxide of Iron*, or *Native Magnet*, is the black oxide of iron, and consists of 71·86 per cent. of peroxide of iron, and 28·14 per cent. protoxide of iron. It is found in great abundance in Sweden and Norway; also in Arabia, Bengal, China, Germany, and occasionally in England and France. It frequently occurs massive, often crystallized, and sometimes in beds of considerable thickness. It is the chief source of Iron in Sweden, and produces iron of most excellent quality, and is much esteemed for making the best Steel.

The magnetic oxide is commonly of a reddish black, or deep grey colour, and is remarkable for its power of attracting iron and steel, to the latter of which it will impart permanent magnetism. This magnetic property, however, does not exist in an equal degree in all the magnetic iron ores. The Arabian,

Chinese and Indian "native magnets" are very powerfully attractive. The ore was first discovered in Magnesia, a town in Asia Minor, and the Greeks are believed to have given the name *Magnes* to the mineral, from which our English word *Magnet* is derived. Some specimens have been found which possessed very remarkable attractive power. It s stated that Galileo had a magnet which, weighing only six ounces, would support a weight of iron equal to ten pounds; and Sir Isaac Newton is said to have worn in a finger-ring a small loadstone—weighing only *three grains*—which would sustain a weight of no less than 750 grains, or two hundred and fifty times its own weight!*

*Artificial Magnets produced by the Native Magnet.*—If we take a lump of Loadstone, and dip it in iron filings, we find, on removing it, that the filings are attached chiefly at the extremities of the Magnet. At these points, therefore, the greatest magnetic power exists, and these are called the *poles* of the magnet, which are respectively termed the *North* and *South poles.* Now this wonderful power, or force—or, as it has been called by some, *fluid*—can be imparted to hard steel, by simply passing a bar of steel several times over the surface of the two poles *in the same direction,* by which operation the bar of steel becomes converted into a *permanent magnet,* one end of which is its *North,* and the opposite its *South* pole. This is termed an artificial *bar magnet.* A *horse-shoe magnet* may be formed in the same way.

*Magnetization by Artificial Magnets.*—Having obtained an artificial magnet, this is capable in its turn of forming other magnets, by one or two very simple operations. The first of these is known as *Magnetization by single touch,* and is thus performed: The bar of steel, which must be hardened and tempered (see page 86), and perfectly clean on all its surfaces, is laid flat upon a

* The most powerful Magnet now known is owned by M. Obellaine, of Paris; it can lift forty times its own weight.

board having a piece of wood of less thickness than the bar, fastened to it at a short distance from one end, to prevent the bar from sliding, as in fig. 16. The magnet is held in an angular position, as in the engraving, and is drawn along the bar, from left to right—always in *the same direction*—many times, and with the *same* end of the magnet.

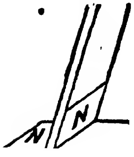


Fig. 16.

Since magnets have generally a groove, or mark, at a short distance from one end, it may be convenient to always operate with the marked end downwards. When the steel bar has acquired as much magnetic power as it is capable of receiving, it is said to be *saturated.*

*Magnetization by double touch* is performed with *two* bar magnets upon a single bar of steel, thus: The steel bar being laid upon the magnetizing board (fig. 17), with one end pressing against the wooden stop, two bar magnets are taken, one in each hand, *with their ends reversed;* they are first held upright in the centre of the steel bar, and are afterwards

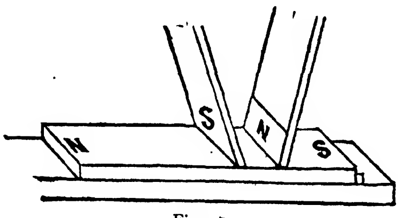


Fig. 17.

separated and drawn along the bar *in opposite directions* to beyond the extreme ends; they are then replaced in the centre of the steel bar as before, and the operation of drawing the magnets along the bar in the same way repeated a good number of times. The bar of steel should be marked at one end by a file, in the same way as the magnets, and the plain, or *unmarked* (South pole or S.) end of the magnet used for the magnetizing process, should be drawn towards the marked end of the steel bar, the magnet with its *marked* end (North pole or N.)

downward, being drawn towards the *plain* end of the steel bar. *Striking the bar*, to produce *vibrations*, is found to increase the absorption, so to speak, of magnetism.

If we bring the same ends, or *poles*, of two magnets close together, they do not attract, but repel each other; but when two *opposite* poles are brought together they attract each other powerfully. The law of *attraction* and *repulsion* is, therefore, this: *the same poles repel each other, and the opposite poles attract each other.*

We have thus seen, that from native magnets, artificial magnets can be produced, and from these again other magnets may be formed; but the unscientific reader will probably be unprepared to accept the statement that magnets can be produced without the aid of either the native or artificial magnets, yet this apparent impossibility we will endeavour to overcome in a very simple way. Nor shall we be surprised if the reader, like ourself, comes to the conclusion that the forces—Electricity and Magnetism—are really one and the same power in different conditions. Faraday found that he could produce *electricity from magnetism*, and we all know that powerful *electrical* effects are obtained even from such very small instruments as the *magneto-electric machine* used for medical purposes. Now, since from Magnetism we can get Electricity, let us see if from Electricity we can obtain Magnetism.

We will take three cells of Callan's Iron battery (p. 64)—although any voltaic battery would answer the same purpose—and allow the electric current produced therefrom to pass through a length of copper wire covered with cotton (*insulated*

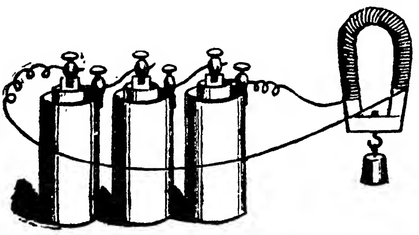

Fig. 18.

wire), coiled round a bar of soft iron bent in the form of a horseshoe (see fig. 18). If, while the current is passing through the wire, we bring a short bar of soft iron near the two ends, or poles of the *Electro-magnet*, as it is called, we shall find that this will be at once *attracted* to it, and, according to the strength of the battery current* and the number of coils upon the bent iron rod, will be capable of sustaining a weight suspended from its hook. If, however, we disconnect one of the wires from the battery, the weight will at once fall, and the electro-magnet will have lost its power of attraction—almost entirely. We say *almost*, because a very trifling amount of magnetism is sometimes retained. Now this little experiment proves that a certain subtle force —which is called *electro-magnetism, or induced magnetism*— had been developed in the bent iron rod, while the current of voltaic electricity was passing round it, but since this power was dependant upon the decomposition of the zinc element of the battery, and is fugitive, so to speak, it hardly seems, as yet, to deserve the name of *magnetism*. We must therefore see if the appropriateness of the title can be established in some other way.

*Magnetization by the Electric Current.*—There are several methods of magnetizing steel by *current electricity*—that is, electricity generated in a galvanic battery. A length of insulated copper wire is formed into a helix, by coiling it round a small ruler or other cylindrical object, and the two ends of the wire are connected to the binding screws of a battery. While the electric current is passing through the helix, a bar of steel or a knitting-needle is passed through its interior, and the steel should be struck by some hard substance occasionally, to make

* With a large number of battery cells, and an Electro-magnet of considerable size, many hundreds of pounds' weight could be sustained in the same way.

it ring or vibrate. After a few minutes, on removing the bar, it will be found to be capable of attracting iron filings or other small iron objects. It is, in fact, *a Magnet,* although a very weak one. A far more powerful magnet may, however, be made with the electro-magnet (fig. 18) by the *touch* processes, in the same way as steel bar magnets are used, and thus very powerful magnets can be obtained *from the electric current passing through copper wire surrounding an iron core.* Faraday discovered *Magneto-electricity*—that is, electricity produced by the influence of a magnet upon insulated copper wire. He found that when a keeper, or *armature* (the piece of soft iron used to preserve the power of magnets), covered with insulated wire, was pulled from the poles of a magnet, *a spark was produced;* and that a current of magneto-electricity was obtained when a copper plate rotated between the poles of a magnet. To this great discovery we owe those marvellous magneto-electric machines which, prior to the discovery of *dynamo-electricity* by Wheatstone and Siemens, proved so serviceable in the electro-deposition of metals.

We thus see that from magnetism electricity can be produced, and from electricity magnetism.* May we not venture to suggest that they are the *same force,* under different conditions? In other words, are not electricity and magnetism—no matter how produced, generated, developed, set free, or brought into action—one and the same power? We are accustomed to speak of the different *kinds* of electricity, as atmospheric, voltaic, frictional, dynamic, and so on; and of magnetism as terrestrial, native, artificial, induced, and electro-magnetism; may they not

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* It would appear that magnetism, like electricity, can be produced, under certain conditions, by *friction,* for we have frequently observed, when filing a piece of steel, that the filings produced have adhered to each edge of the file.

all be the same force under different conditions? May not magnetism be simply condensed or accumulated electricity?

The connection between electricity and magnetism and our Lump of Iron may be further illustrated by reference to the dynamo-electric machine—that wonderful invention of comparatively recent date, which is providing us with a pure, wholesome, brilliant light of marvellous power and intensity. The dynamo-electric machine also enables the electro-metallurgist to deposit gold, silver, copper, nickel, and other metals with great rapidity and economy. It is also used in separating copper and other metals from their impurities, and will possibly in the future supersede, to some extent, the ordinary processes of refining metals by furnace heat.

We have seen what a close connection there exists between electricity and magnetism; let us now see how *dynamo-electricity* is produced, and this we cannot do better than in the language of Dr. Siemens himself, who thus explains the principle upon which the current is produced:—

"Induced currents are directed through the coils of the electro-magnets which produce them, increasing their magnetic intensity, which in its turn strengthens the induced currents, and so on, accumulating by mutual action until a limit is reached."

The electric current is produced by the rapid rotation of coils of insulated copper wire between a series of soft iron electro-magnets. The rotating coil of wire is called the *armature*, and is caused to rotate at a very high speed, by which the power gradually increases. "The electric current," says Dr. Siemens, "thus becomes stronger and stronger, and the armature, therefore, revolves in a magnetic field of the highest intensity, the limit of which is governed by the limit of saturation of the soft iron." Thus we see that dynamo-

electricity is produced—not from *permanent steel magnets*, as in the magneto-electric machine, but from *soft iron* electro-magnets. "The name dynamo-electric machine is given to it because the electric current is not induced by a *permanent magnet*, but is accumulated by the mutual action of electro-magnets and a revolving wire cylinder, or armature. It is found that as the dynamic force required to drive the machine increases, so also does the electric current; it is therefore called a dynamo-electric machine."

Magneto-electricity, electro-magnetism, and dynamo-electricity have each been employed as a motive force for driving machinery, and it is far from being improbable that at some not very distant period, steam-power will have to yield to electricity and magnetism the proud position it has held so long and so well as a motive force.

Another and more recent application of magnetic influence may be seen in Bell's speaking telephone, in which a permanent bar-magnet, inserted in a boxwood reel of fine silk-covered copper wire, and above which is a vibrating disc of ferrotype iron, plays an important part, since it is the feeble currents set up by the vibrations of the soft iron disc in front of the magnet which conveys the sound through the conducting wires to the distant receiving instrument.

# INTERESTING NOTES.

ALTHOUGH the conversion of crude cast-iron into malleable iron is, at the present time, conducted under more favourable conditions than were possible in the days of Henry Cort, the process which he developed—even if he did not actually originate it—is essentially the same process which is being worked to this day. To that public benefactor we also owe the substitution of cylinder-rolling for the hammering process in use before, and up to, the time of his great improvement being adopted. Speaking feelingly upon the subject of Henry Cort's scandalous treatment by the Government of his time, and the unnatural neglect which he experienced from those who had benefited so greatly by his inventions, Mr. Fairbairn* says:—"It is perhaps not generally known that Mr. Henry Cort expended upwards of £20,000 in perfecting his inventions for puddling iron and rolling it into bars and plates; that he was robbed from the fruit of his discoveries by the villainy of officials in a high department of the Government, and that he was ultimately left to starve by the apathy and selfishness of an ungrateful country. When these facts are known and it has been ascertained that Mr. Henry Cort's inventions have conferred an amount of wealth on the country equivalent to £600,000,000 sterling, and have given employment to 600,000 of the great working population of our land for the last three

* "Iron, its History, Properties," &c. By William Fairbairn.

or four generations, we are surely justified in referring to services of such vast importance, and in advocating the principle that some substantial proofs of the Nation's gratitude should be afforded to rescue from penury and want the descendants of such a benefactor."

At the present day, a successful Inventor would probably be honoured by a knighthood, or a baronetcy—at all events both the public and the press would take care that his Government did not plunder him.

In the author's "History of a Lump of Coal" he called attention to the fact that the great services which William Murdock, the inventor of gas illumination, had rendered this country—indeed every civilized country—had never been recognized by a public monument. The suggestion met with some attention at Redruth, Cornwall, where the illustrious engineer had resided, and where his first experiments were made, and it was proposed to erect a suitable memorial in the parish church of that town. Believing, however, that the matter was not merely of local, but of national importance, the author wrote to *The Times* newspaper in May last, suggesting that some movement should be set on foot to establish a suitable memorial in London, near the spot (close to the Houses of Parliament) where gas-lighting was first publicly adopted in the Metropolis. *The Times*, however, did not think proper to insert the letter referred to, but a few months after put forth the proposal *as its own* in a leading article, and as a consequence a committee was formed, of which the late lamented Sir W. Siemens was the chairman. It is not the first time—nor the fifth—that the author's suggestions, including the Workmens'

Industrial Exhibitions and the *red* pillar-letter-boxes, have been thus unceremoniously filched from him.

The black colour of Irish bog-oak is due to Iron, and some specimens in the author's possession are as intensely black and also as hard as ebony. A specimen of bog-yew, however, also in his cabinet, is *not* black, but of a light cedar colour.

The various tints in ornamental marbles generally proceed from oxides of Iron.

Some mineral waters are impregnated with Iron, hence they are called chalybeate waters (from *chalybs*, Iron).

Mythological records assign the discovery of Iron to Vulcan, the deity that presided over fire, and was the patron of all artificers who worked in metals. Newton has supposed Vulcan to be identical with Cinyras, King of Lemnos, who invented the anvil, the tongs, and the smith's hammer, and who was the only king celebrated in history as a worker in metals.

Rhind, in exploring the tomb of Sehan, which had not, he believed, been opened for nearly two thousand years before, discovered on the doors of the inner repositories, hasps and nails of Iron; but he found nothing to indicate that in the time of Sehan the Egyptians made use of Steel.

According to the popular tradition of Sheffield, possession was obtained of Huntsman's secret by the knavish and heart-

less trick of a rival steel maker. This person, it is reported, presented himself, in the garb of a beggar, at the entrance to the Attercliffe Works, under conditions most calculated to excite the sympathy of the workmen; it was during a dark winter's night, when the snow was falling fast, and this mean and skulking vagabond prayed for shelter and warmth in the casting-house. The prayer was granted—who could have refused it?—and at length the prize was secured. This may be a mythical story, or it may be absolutely true. Many a time the same kind of artifice has been resorted to. It is a low theft, which no man having the least feeling of honour could possibly commit. . . . . In London an example of this kind occurred which attracted much attention. Three persons, *all foreigners*, conspired to obtain access to the works where aniline was being largely manufactured for the production of the now well-known and beautiful mauve and magenta dyes. As usual, a conference was held at a public-house with one or two of the chief workmen, who apparently consented to aid in the plot. The night which had been appointed for the execution of this plot arrived: one conspirator entered, but the other two, whether from misgiving or cowardice, remained where they could, if necessary, make a hasty retreat. All was dim, if not actually dark; but no sooner had the leader fairly entered than the gas was turned full on, and he stood, confronted and dismayed, before the proprietors of the works. He was tarred from head to foot, and sent adrift in the street crying for mercy, and seeking protection from the police. He was confined to his bed several days in consequence of the severe irritation to his skin. He was righteously served; and would that every perpetrator of the like offence had been caught and treated the same way!—*Dr. Percy.*

This anecdote reminds the author of a dastardly trick practised upon his father at a time when he was about to demonstrate a new chemical process at a well-known manufactory the north of England. In order to screen the process from the observation of the workmen, the proprietor, with exuberance of fuss, directed that a sheet of tarpaulin should be suspended from the rafters above, which was done; but lo! while the process was being manipulated, a human eye—*not* the property of a workman—was observed steadfastly peering through a hole in the canvas! This was observed, in silence and disgust, and the process *purposely* spoiled by the introduction of an extra chemical substance. The mean and despicable trick was designed to rob the inventor of his process, and thus save the cost of paying for it.

Homer, in his "Odyssey," says, "As some smith or brazier plunges into cold water a loudly-hissing great hatchet or adze, tempering it, for hence is the strength of Iron," &c. Since neither iron nor brass can be tempered in this way, possibly the so-called *iron* was in reality *steel*.

So great is the affinity of iron for carbon that, under certain conditions, it will absorb this element from coal gas (carburetted hydrogen). Mr. Mackintosh, of Glasgow, once took out a patent for making steel upon this principle. A cylindrical furnace was employed, in which bars of iron were suspended, and a stream of coal gas was allowed to circulate freely round them, the bars being kept at a bright red heat. The steel was excellent, but the process was not economical.

Many years ago, the late Professor Faraday and Mr. Stodart made a series of experiments to alloy steel with silver, platinum,

rhodium, and iridium. Steel refused to take up in fusing more than 1-500th part of silver, but with this minute proportion it was said to bear a harder temper, without losing its tenacity. When pure iron was substituted for steel, the alloy formed was much less oxidizable than pure iron. With 3 per cent. of iridium and osmium, an alloy was obtained which had the property of tempering like steel, and of remaining clean and bright under conditions where simple iron became covered with rust.

"And mine arms shall break even a bow of steel" (Psalm xviii. 34).

*Iron from a Morass.*—"These masses of oxide of iron," said Dr. Mantell, referring to some specimens exhibited at one of his delightful lectures, "were dug up in a marshy soil, near Bolney, in Sussex, and are of the same nature as the substance called bog-iron ore, which occurs in peat. The ebony colour of the woods from Ireland [bog oak] which we have already examined has been occasioned by an impregnation of Iron. Specimens of bog-iron ore are not uncommon in the superficial loam and gravel of this part of England."

The leaves and seed vessels which occur in the Ironstone nodules have in many instances undergone a metallic impregnation. Brilliant sulphuret of iron, or pyrites, in some examples permeates the entire vegetable structure.—*Mantell.*

Ehrenberg, to whom we are largely indebted for opening this new field of inquiry (concerning *infusoria*), has discovered this class of animals in numerous deposits. Thus the ferruginous,

or ochreous film or scum, seen on the water of marshes, or of stagnant pools, or collected at the bottom of ditches, sometimes forming a red or yellowish mass, many inches thick, without any consistence, which divides upon the bare touch into minute atoms, and when dried resembles oxide of iron, is found to be wholly composed of the shields of infusoria (*gaillonella ferruginea*). The formation of bog-iron ore is supposed to be in a great measure dependent upon these animals. A ferruginous mass from a peat bog, "which appears to have owed its origin to the action of volcanic heat at the bottom of the sea," entirely consisted of shields of infusoria (*naviculæ*). The semi-opal and the tripoli of the tertiary deposits are wholly composed of the fossil remains of this class of animals.—*Mantell.*

*Sulphuret of Iron.* — The same author observes:—"Iron pyrites is the only metalliferous ore that occurs abundantly in the chalk of England. The large nodular masses that are found on the downs and in ploughed fields, are commonly termed *thunder-bolts.*"

The bones and scales of the fossil fishes "are invariably coloured," says Dr. Mantell, "with a ferruginous stain, arising from a curious chemical process; sulphuretted hydrogen was evolved during the course of putrefaction, but the sulphur, entering into combination with the Iron contained in the water, sulphuret of iron was formed, and thus the fossil fishes have derived the rich colour which so beautifully contrasts with the white chalk by which they are surrounded."

A very slight acquaintaince with natural science will exhibit the wisdom of a bountiful Creator in the wide diffusion and

abundant supply of Iron and Coal, two of the greatest boons conferred upon the human race. If we refer to the history of the past, and trace the change from barbarism to a state of intellectual culture, we see at every step the contrivances and appliances of the cunning workers in Iron. These have always been the associates of mental progress and the forerunners of supply to the wants and necessities of our social existence.—*Fairbairn.*

"Recently," wrote Dr. Page, in 1869, "the Ironstones of Cleveland, in Yorkshire, which occur in thick beds, and over a large extent of that county, has added a new industrial importance to the oolite and the wealth of that district of England—the busy population of northern Yorkshire and Middlesborough being the direct result of this discovery." The statistics of the Iron produce of the Cleveland district at the present day, which give the manufacture of pig iron as upwards of 2,000,000 tons in one year, will show what astounding proportions the Iron industry—in this one district alone—has attained within a comparatively short period.

Mr. Mushet thus describes the various phenomena which attend the flowing out of Iron from the furnace:—"When fine, or supercarbonated crude iron, is run from the furnace, it throws off an infinite number of brilliant sparkles of carbon. The surface is covered with a fluid pellicle of the most delicate folds. At first the fluid metal appears like a dense ponderous stream; but as the collateral moulds become filled it exhibits a general rapid motion, from the surface of the pigs to the centre of many points; millions of the finest undulations move upon each mould, displaying the greatest nicety and

rapidity of movement, conjoined with an uncommonly beautiful variation of colour, which language is inadequate justly to describe."

*Artificial Petrifaction.*—Mr. Parkinson having observed that the leaf in Ironstone nodules could sometimes be separated in the form of a carbonaceous film, Mr. Goppert, who had also noticed the same fact, determined to carry out a series of experiments upon the subject. He imbedded some fern leaves in clay, dried them in the air, and afterwards exposed them to a red heat, by which he obtained striking resemblances to fossil plants. The leaf was found to be brown, shining black, or entirely dissipated, the impression only remaining, according to the degree of heat applied. In the latter case, the clay was stained black, thereby indicating that the colour of coal shales is derived from the carbon of the plants they enclose. Plants soaked in a solution of sulphate of iron were afterwards dried and heated until every trace of vegetable matter had disappeared, and the oxide of iron resulting from the calcination of the iron salt presented the form of the plant.

Mr. John H. Wilson, of Liverpool, proposes to make cast crucible steel by running the iron, before puddling, into a reverberatory furnace lined with soft pulverized hematite, strong heat being applied, to extract the phosphorus, sulphur, silicon and manganese.

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The electric conductivity of Iron is supposed to be influenced by the amount of carbon present in the metal. Iron containing the smallest quantity of carbon is the best conductor of the electric current.

Both at Dudley and in South Wales, casts of shells belonging to the genus *Unio* are observed in the Ironstone.

The exports of Pig Iron, Bar angle railway, Tin plates (tinned sheet iron), Steel, &c., form a very important item in our trade with foreign countries. In 1878, the total value of these exports was £18,393,240; in 1879, £19,417,363; and in 1880, £28,307,175.

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To give some idea of the enormous magnitude of our Coal and Iron industries: in the year 1880 we removed from Nature's subterranean storehouse no less than 146 millions of tons of Coal, of the value of £62,395,414, and 18 millions of tons of Iron ore. The value of the pig iron of this year was £19,373,082.

The following curious extract from Gabriel Plattes' "*Hidden Treasure*," published in 1659, is worth reading: "Now whereas Gold is not subject to putrify in the Earth by any Length of time, it is probable enough that other metals might be generated with it at first, and afterwards putrified and consumed from it in Length of Time, leaving the Gold pure. For I have drawn Iron, or a substance like to Filings or Atoms of Iron out of Grain Gold that was brought from *Guinea* with a Loadstone, which seemed to be Iron not fully putrified and turned to Earth. And the Reason why the hotter the country is the richer the Minerals are, can be no other but the same that roasted meats are sweeter than boiled meats, the Reason whereof is plain, for the rawish and unsavory part is inbaled by the Heat of the Fire, leaving the sweetest part behind." What a valuable contributor the author of these lines would have been to a comic paper of our own day!

For tempering small articles, it has been proposed to employ a mixture composed of sperm oil, tallow and wax; and, by adding resin to the mixture, it is said to be suitable for tempering larger articles. After some months' use the mixture loses its tempering value and must therefore be renewed.

The intense brilliancy of the flame which issues from the mouth of Bessemer's converting vessel renders it difficult for the workmen to determine when to stop the blast at the right moment. This led Professor Roscoe, many years ago, to submit the flame to *spectrum analysis,* with a view to substitute this test for the eye of the workman. Mr. Fairbairn thus describes Mr. Roscoe's interesting experiments: "The conversion of cast-iron into cast-steel usually occupies from fifteen to twenty minutes, according to the varying conditions of weather, quality of ore, strength of blast, &c. If the blast be continued for ten seconds after the proper point has been attained, or if it be discontinued ten seconds before that point is reached, the charge becomes either so viscid that it cannot be poured from the converting vessels into the moulds, or it contains so much carbon as to crumble under the hammer. Up to the present time, the manufacturer has judged of the condition of the metal by the general appearance of the flame which issues from the mouth of the converting vessel. Long experience enables the workman to detect, with more or less exactitude, the point at which the blast must be cut off.

"It occurred to Mr. Roscoe that an examination of the spectrum analysis of the flame might render it possible to determine this point with scientific accuracy, and that an insight might be gained into the somewhat complicated chemical changes which occur in this conversion of cast-iron into steel. At the request of Messrs. John Brown and Co., of the Atlas

Works, Sheffield, Mr. Roscoe investigated the subject, and succeeded in obtaining very satisfactory and interesting results. The instrument employed was an ordinary Steinheil's spectroscope, furnished with photographic scale and lamp, and provided with a convenient arrangement for directing the tube, carrying the slit towards any wished-for part of the flame, and for clamping the whole instrument in the required position. By the help of such an arrangement, the spectrum of the flame can be most readily observed, and the changes which periodically take place can be most accurately noted.

"The light which is given off by the flame in this process is most intense; indeed a more magnificent example of combustion of oxygen cannot be imagined, and a cursory examination of the flame spectrum in its various phases reveals complicated masses of dark absorption bands and bright lines, showing that a variety of substances are present in the flame in the state of incandescent gas. By a simultaneous comparison of these lines in the flame spectrum with the well-known spectra of certain elementary bodies, the presence of the following substances in the Bessemer flame, viz., sodium, potassium, lithium, iron, copper, phosphorus, hydrogen and nitrogen were detected. . . . Already the investigations are so far advanced that the point in the condition of the metal at which it has been found necessary to stop the blast, can be ascertained with precision; and thus, by the application of spectrum analysis, that which depended on the quickness of vision of a skilled eye, has become a matter of exact scientific observation."

*Separation of Iron Ore by Magnetism.*—Mr. King, of the Ballycorus Mines, Isle of Man, crushes his ore, which is composed of galena, blende and spathose iron ore, and after separating the galena, roasts the residue, at a dull red heat, in revolving retorts, thus producing a magnetic oxide of iron, by decomposing

the carbonate of that metal. The ore is then put into drum wheels having magnets arranged radially within; here the magnetic iron is separated by attraction, and the blende left to escape clear.—*Engineer*.

The Americans are fast rendering the importation of Iron into the States unnecessary. A number of western furnaces have been making a pig-iron that so closely resembles the Scotch pig that it has acquired the name of "American Scotch," and it is largely used in foundry work in place of the Scotch article. The ores used are native *Blackband* and *Shell*. The Americans even go so far as to say that their own "Scotch" iron is superior in strength to that from the Land o' Cakes.

The Hon. A. S. Hewett, of New York, gives the following estimate of the world's production of Iron. The figures for Great Britain and France are for the year 1874; Austria and Hungary, 1873; and the other countries, 1871 or 1872.

| | Tons. |
|---|---|
| Great Britain | 5,991,000 |
| United States | 2,401,000 |
| Germany | 1,600,000 |
| France | 1,360,000 |
| Belgium | 570,000 |
| Austria and Hungary | 365,000 |
| Russia | 360,000 |
| Sweden and Norway | 306,000 |
| Italy | 73,000 |
| Spain | 73,000 |
| Switzerland | 7,000 |
| Canada | 20,000 |
| South America | 50,000 |
| Japan | 9,000 |
| Asia | 40,000 |
| Africa | 25,000 |
| Australia | 10,000 |
| Total | 13,260,000 |

*Magnetism in Iron Rails.* — A paragraph has recently been running through the papers, announcing that magnetism has been observed in rails that have been laid some time, on the railroad between Marseilles and Rognac. This reminds us that the same observation was made by M. Heyl, engineer of one of the German railways, in 1875, who attributed the magnetism to "the running of the trains, and to the shocks, frictions, &c., thereby produced." He further remarked that the "hypothesis of electric currents, induced or direct, must be rejected, since it is negatived by direct experiments on the subject with suitable apparatus." In the same year (1875) the author published a pamphlet, in which he called attention to the vast amount of electricity which is generated by the steam from locomotives, and supported his statement by quoting the following letter addressed to the late Professor Faraday by Mr. Armstrong, upon this subject,* which gives the first account we have of electricity being produced by jets of steam.

"The cement by which the safety-valve was secured to the boiler had a crack in it, and through this fissure a copious horizontal jet of steam continuously issued. Soon after this took place, the signal man, having one of his hands accidentally immersed in the issuing steam, presented the other to the lever of the valve, with a view to adjusting the weight, when he was greatly surprised by the appearance of a brilliant spark passing between the lever and his hand, and was accompanied by a violent wrench in his arms wholly unlike what he had ever experienced before." Sometime after this Mr. Armstrong, following up the subject, made a series of highly-interesting

* Mr. Armstrong constructed a machine, called the *hydro-electric machine*, which was exhibited at the Polytechnic Institution, about the year 1844, and which produced an electric current of considerable power.

experiments. By standing on an insulated stool, and holding with one hand a light iron rod, immediately above the safety-valve of a locomotive engine, while the steam was freely escaping, and then advancing the other hand towards any conducting body, he obtained sparks of an inch in length; when a bunch of wires, attached to the rod, was held, points downward, in the issuing steam, sparks *four inches long* were drawn up from a round knob on the opposite extremity of the iron rod. These results clearly show that electricity is largely generated while steam issues from the boilers.

Now there can be no doubt that the electricity generated in this way by our locomotives, passes directly through the metal work of the engine to the iron rails; and since we know that Iron is capable of acquiring a small amount of magnetism, is it not more than probable that the magnetism observable in railway metals is in reality due to the *absorption* of a portion of the electricity generated in locomotive engines by jets of steam? By the way, Faraday was of opinion that the steam *per se* does not yield electricity, but that the current is produced when the steam comes in contact with *water*—which, of course, the condensed steam readily furnishes. We have often thought that if the railway metals could be insulated from contact with the earth, that the current generated by the locomotive engines could be stored and utilized for lighting up the stations and tunnels. Indeed it is possible to conceive the notion of each locomotive carrying, at night-time, a head-light illuminated by the current generated by its own steam.

Iron is thus classified: 1. Cast-iron or Pig-Iron, which contains the most carbon of any manufactured Iron. It is not

ductile, and cannot be welded; it is of variable hardness, and melts at a high temperature. According to its adaptability to the uses of the founders, it is called "forge" or "foundry" Iron. 2. Wrought or Malleable Iron. This iron is soft, malleable, and capable of being welded at a white heat. It melts only at the very highest temperature, and does not become hardened (like steel) by being heated and suddenly cooled. 3. Steel, which contains more carbon than malleable-iron, but less than cast-iron. It is both fusible and malleable, and may be welded at a lower temperature than wrought-iron. It may be hardened by being heated and suddenly cooled, and softened to any requisite degree by the process known as *tempering*.

While it would be unnecessary to give a complete list of the numerous works referred to in the preparation of this little book, we have much pleasure in acknowledging those to which we have been most indebted for much valuable information, namely, Day's "Prehistoric History of the Uses of Iron and Steel;" Tomlinson's "Cyclopædia of Useful Arts;" Fairbairn's "Iron, its History, Properties, &c.;" Dr. Percy's "Metallurgy: Iron;" Ure's "Dictionary of Arts, Manufactures, &c.," and "Chemistry, as Applied to the Arts and Manufactures."